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CACAO RESEARCH.

THE Sixth Annual Report on Cacao Research for 1936 which has recently been issued covers the respective activities of the botanical and chemical sections of the Cacao Research Scheme. Progress by the botanical section during the period under review has been limited owing to staff reduction. Propagation work, nevertheless, has gone on steadily and the nurseries were sufficiently established for supplying material for field experiments during the present year. Attention has been directed, in particular, to the problem of pollen compatibility and its influence on yield. The most striking result obtained from previous studies on this subject has been to demonstrate the occurrence among such Trinidad cacao trees as have been examined of self incompatibility, or failure to set fruit on self-pollination. This condition, in cacao, was believed at one time to fluctuate and this discovery was thought to explain the intermittent setting exhibited by a great many trees. Investigations at present in progress suggest that trees are either self compatible or self incompatible although self-fertilized cherelles are occasionally produced. There is no evidence yet to show that a self incompatible tree can become self compatible. The number of self incompatible trees has also been found to be exceptionally large. The assumption is made that all pods on self incompatible trees are the result of cross pollination and that the removal of surrounding trees would result in failure to set any crop at all. The presence of a large number of self incompatible trees may, therefore, be regarded as a depressing influence on yield. The subjects of pollen compatibility and of cross fertilization, of which little is known, have a bearing of first rate importance on yield and the progress of the researches into both these problems will be watched with much interest.

The work of the chemical and ecological section for the year 1936 has mainly concerned the biochemistry of cacao and less attention has been devoted to ecology, while studies of environmental factors in the field have solely comprised an extension of the soil investigations.

A detailed soil survey of the Rio Claro-Tableland-Princes Town district has been completed and an accurate soil map of the area prepared. A detailed soil survey of the Sangre Grande-Manzanilla district has also been commenced.

A conspicuous symptom of unsuitable cacao environments, particularly with regard to deficiency of available soil potash, has been discovered by means of sand culture experiments and detailed

soil surveys. The symptom is described as a marginal leaf-scorch, and cacao leaves prone to scorching, or already showing symptoms, reveal characteristic chemical composition as determined by ash analysis.

The large scale field manurial experiments on cacao have been continued and the results obtained up to the end of 1936 are discussed in the Report. A new departure in the investigation of cacao soils was initiated during 1936 when some 190 soil samples, taken from 19 profile pits representative of cacao growing lands of the Gold Coast, were examined. An account of some Gold Coast cacao soils is given where comparisons are made between their main geological, physical and chemical features with those of some West Indian cacao soil types.

The biochemical investigations have been directed mainly to elucidate the biochemical factors which control "quality" in raw cacao in so far as the development of colour, flavour and aroma of the roasted product is concerned. Four aspects of this problem are being investigated: the possible differences in chemical composition between well known varieties of cacao; the effect of ripening on biochemical composition; the effect of environmental growth factors such as climate, soil type and manurial treatment; and the effect of fermentation and drying. In view of the rôles which tannin-like substances and theobromine are believed to play in controlling taste and flavour, chief consideration has been given to methods for estimating these substances in raw cacao. Preliminary results have shown that the tannin and theobromine contents of the raw bean may vary considerably but as the variations were not regular it has not been possible yet to reach definite conclusions. In the case of fermentation, however, marked differences were revealed between unfermented and fully-fermented beans. Tannin was found to increase in the kernel during fermentation while theobromine was found to decrease considerably in the kernel and to increase proportionately in the shell. Thus it is suggested that theobromine, rather than tannin, may be the chief factor concerned in the loss of bitterness during fermentation, and in the harsh taste of "low quality" cacao. Preliminary determinations of fat content have shown that its amount does not reach a maximum until the bean is fully ripe. The biochemical problems concerned in the definition of "quality" of cacao are extremely complex and difficult but further work along the lines indicated is contemplated.

BANANA LEAF SPOT.

We have already drawn attention this year to the banana leaf spot caused by *Cercospora musae*. This disease has now attained severe proportions in the Caribbean area including the Islands and Mainland and has long been known as a serious disease in Fiji and Queensland. An article in the March issue of this Journal (1) briefly summarised relevant researches by Dr. Stahel in Surinam. This was followed by Dr. Wardlaw's account (2) of its outbreak, spread and intensification in Trinidad where he recorded it for the first time towards the end of 1933. An opportunity is now taken to publish in full Dr. Stahel's extensive mycological study which constitutes a very important contribution to our present knowledge of this disease. As a result of his detailed investigations it has been possible to postulate methods of control by spraying. These have already met with some success in Surinam. In that country, however, conditions for spraying are particularly favourable since plantations are situated on empoldered land with numerous adjacent intersecting waterways. Where bananas are grown on a large scale or on hillsides away from water supplies, spraying operations though not necessarily insuperable will be much more difficult and costly.

Outstanding facts emerging from Dr. Stahel's researches are that the disease only attacks the youngest leaves and takes at least five weeks to develop and become visible: preventive treatment must therefore be applied during the very early stages of leaf emergence and unrolling if the disease is to be successfully controlled.

(1) *Tropical Agriculture*, Vol. XIV, No. 3, p. 59.

(2) *Tropical Agriculture*, Vol. XIV, No. 4, p. 117.

OBITUARY.

Sir Eliot de Pass, K.B.E.

Sir Eliot Arthur de Pass died at his home in London on July 11th at the age of 86 after a long and useful career of public service.

Born in 1851 he was educated privately at Brighton and Hanover. From 1873 to 1878 he was special commissioner and attorney of the Windsor and Annapolis Railway, Nova Scotia. He then left Canada to embark on a commercial career and in 1880 became a partner in the New York firm of Lascelles & Co. which was engaged in trade with Jamaica and the West Indies. Returning to England in 1884 he founded the firm of E. A. de Pass & Co. of which he was Chairman. He was a very active member of the West India Committee of which he was chairman from 1928 to 1936 and president at the time of his death. He was co-opted a Governor of the Imperial College of Tropical Agriculture in 1925, and was vice-president of the British Empire Producers' Association and of the West Indian Club.

Sir Eliot was knighted in 1930 and created a K.B.E. in the last New Year honours.

During his lifetime Sir Eliot devoted much of his time and energies to West Indian affairs in which he was deeply interested. His death removes an outstanding personality whose signal services to the West Indies, wise counsel and soundness of judgment will be greatly missed. To his widow and family we extend our very deep sympathy in their bereavement.

OBITUARY.

The late F. W. Urich.

By the death of Mr. F. W. Urich, which occurred on the 29th July, after an illness of nearly a year's duration, an eminent entomologist and a justly popular citizen has been lost to the Colony. He was indeed so closely identified with the zoological work of this part of the world and so widely informed that it is doubtful if his place can ever be adequately filled.

Urich was a particularly outstanding example of the "born naturalist", a type which is all too rare in these days. He was one of those students to whom scientific observation of living things is second nature and in his own subject, he certainly had an infinite capacity for taking pains. No group of animals ever seems to have been too insignificant to attract his attention with the result that his knowledge of species and of their modes of life was monumental.

Although he held public office as an entomologist with distinction for many years, and acquired international repute in his profession, Urich was very largely self-trained. His formal training seems to have occupied only a few months spent in Switzerland and Germany at an early stage of his career. Following this brief European sojourn, he appears to have abandoned the idea of a scientific profession for a time and he entered the public service of his native colony soon after his return.

Even at this early time, however, his observations on natural history had gained him a good deal of attention and his repute in the Colony was such that the Board of Agriculture appointed him as their entomologist, for which purpose, he was first seconded and later transferred from his civil appointment. At a much later date, Urich left the service of the Board to join the staff of the Department of Agriculture as Government Entomologist. This appointment he held until his retirement from Government service in 1926, when he was appointed Assistant Professor of Zoology in the Imperial College of Tropical Agriculture, largely through the instrumentality of the late Sir A. E. Shipley, who had the highest opinion of Urich's professional work.

A lifetime of distinguished technical work can hardly be summarised, but among the many problems which he studied may be mentioned his work on the Cacao Thrips and on the Sugar-Cane Froghopper. His work on the former pest attracted much attention and he spent some time in the neighbouring colonies giving advice on control measures and even travelled to San Thomé at the instance of the Portuguese Government. He was also one of the very first entomologists to recognise the possibilities of the biological control of insect pests and he did much to put this on a scientific basis. Several outstandingly successful introductions of predacious and parasitic insects into other countries from Trinidad are the direct outcome of his pioneer work in this field.

As a field naturalist, Urich was unsurpassed. His knowledge of the local fauna was truly amazing and he has done much to encourage its study by others, being a foundation member of the Field Naturalists' Club and an active participant in its functions to the end of his life. His reputation abroad was, indeed, as much due to his work as a naturalist as to his more strictly official achievements, a reputation which his considerable linguistic ability did much to assist.

But apart from his technical qualifications, Urich will long be remembered for his engaging personality. He was a man of simple, yet cultivated tastes in many ways and he had the gift of making and retaining friendships. Several generations of students from the Imperial College will have kindly recollections of his association. Naturally, we who worked in his own department knew him best, but for several years he came into contact with members of other departments, particularly through the week-end excursions which he used to organise to Aripo, Tucuche and other parts of the Northern Range, of which he was so fond.

Up to the commencement of his last and fatal illness, Urich was actively engaged in biological research. His services had been retained for the study of the local bats, in connection with the campaign against paralytic rabies. In this subject he made some notable discoveries on the feeding habits of the carnivorous bats, which have a great importance in control operations. It is fortunate that he was able to publish at least a part of his work on this subject before his illness overtook him.

In mourning an honoured colleague and friend, it is fitting that we should pay tribute to his active and useful life and to those more personal qualities which made him so deservedly popular among his associates.

A VARIETY TEST ON SUGAR-CANE.

By R. Cecil Wood, M.A. (Cantab.), Dip. Agric.

In 1930 an experiment was started on the College Estate by the Agricultural Department of the College to compare a number of thin canes which it was thought might be suitable for some of the poorer soils of this island. Along with Uba, a cane which is already well known in Trinidad, were a number of new seedling canes, from Java, Coimbatore and Mayaguez, as well as the famous P.O.J.2878 which was at that time rather a novelty.

The experiment was originally planned to run for the three crops which it is the usual practice to take in Trinidad, but it was found that the yields were keeping up remarkably well and the experiment has now run on for six harvests—one plant and five ratoons. It could with profit be continued perhaps a few years more, but it is felt that little further information could be obtained, and the land is wanted for other purposes.

The results have been reported year by year in this Journal* and in presenting a complete account of the experiment, however brief, a certain amount of recapitulation is unavoidable.

Procedure.

Area.—The field chosen for the experiment was a deteriorated alluvial yellow loam, lying on the dividing line between the swamp and lagoon alluvial soils to the south, and the hill detrital soils to the north. This type of soil is acidic in reaction and in general of low fertility but this field had been limed and otherwise fairly well treated. Though, like most of the College land, it had only recently been cleared, and is in consequence lacking in uniformity, it is hoped that the lay-out of the experiment has largely eliminated the effects of this irregularity.

Manure.—The treatment has on the whole been liberal.

1930-31—7 tons limestone in April. A very heavy crop of Sunnhemp was ploughed in, in August, and in September 12 tons of Pen Manure. Canes planted in October.
1931-32—Nil.
1932-33—Sulphate of Ammonia 1 cwt. (approximately) to ratoons.
1933-34—Sulphate of Ammonia 1 cwt.
1934-35—Sulphate of Ammonia 3 cwts. Muriate Potash 1 cwt.; Superphosphate 1 cwt.
1935-36—Sulphate of Ammonia 3 cwt.
1936-37—Sulphate of Ammonia 3 cwt.

Planting.—The canes were planted in September and October, 1930, in shallow trenches, five feet apart, and four feet apart in the row, and were first reaped in April, 1932, when 19 months old. The ratoons were harvested at yearly interval thereafter.

Treatment of Ratoons.—The usual procedure is to rake the trash off alternate rows, as soon as possible after harvest. These uncovered strips are then ploughed, cultivated and manured, after which the trash is raked back to permit of the other rows being similarly treated. Finally the trash is evenly spread over the field.

Cane Varieties.—The following varieties were grown:—

P.O.J. 36	P.O.J. 826	Co. 281
P.O.J. 213	P.O.J. 2878	M. 36
P.O.J. 234	Co. 213.	

Experimental Lay-out.—Each plot was 7 rows in width (35 feet), and each row contained 22 stools (88 feet), so that its area was 3,080 square feet, or 0.07 acre. There were 4 randomised blocks

* *Tropical Agriculture* IX, 290: X, 188: XI, 201: XII, 35: XIII, 146.

Table I.

Variety.	Tons Cane per Acre.						Total for Six Crops.				
	Plant.	1st	2nd	3rd	4th	5th	Cane Tons.	Per cent. Uba.	Sugar Tons.	Per cent. Uba.	Tons cane to 1 ton sugar.
P.O.J.2878	63	30	34	30	41	36	234	142	23.2	172	10.1
Co.213	57	34	26	23	30	27	197	119	17.0	126	11.6
M.36	**48**	**32**	**25**	**22**	**29**	**29**	**185**	**112**	**15.7**	**116**	**11.8**
Co.281	**47**	**31**	**24**	**15**	**21**	**28**	**166**	**101**	**14.8**	**110**	**11.2**
P.O.J. 36	33	26	22	21	27	23	152	92	13.9	103	10.9
Uba	**37**	**26**	**19**	**23**	**31**	**29**	**165**	**100**	**13.5**	**100**	**12.4**
P.O.J.213	23	20	17	17	21	23	121	73	13.4	99	9.0
P.O.J.234	30	23	20	14	19	19	125	76	13.2	98	9.5
P.O.J.826	33	20	13	7	16	13	102	62	10.6	79	9.6

Significant differences on total cane 5.84 tons, on total sugar .54 tons.
M.36 and Co.281 are not included in the Statistical Analysis as there are only 2 plots of each.

with 8 plots in each block. Each variety occupied one plot in each block with the exception of Co.281 and M.36 which, on account of shortage of planting material, only occupied 2 plots each.

Experimental Data.

The complete returns for weights of cane harvested are given in Table I along with the total weight of sugar obtained, the totals of cane and of sugar being also expressed as percentages of Uba which is taken as a standard of comparison.

It will be observed that there are very large differences between the total yields of the different canes, the best canes yielding 42 per cent. greater weight of canes than Uba, while the poorest yields 38 per cent. less. There are evident differences moreover in their ratooning qualities; the plant cane crops of P.O.J. 2878 and Co.213 represent 27 and 29 per cent. of the total for the six crops, while the plant cane crop of Uba is only 22 per cent. of the total. The general recovery shown in the last two seasons' crops is presumably due to the heavier manuring given the canes. This effect is masked in the case of the third ratoon crop by unfavourable growing weather.

The total yield of sugar is of course the main criterion by which the canes are to be judged, but there are qualifications. Firstly the amount of cane which must be crushed to give that quantity of sugar, and secondly the ease with which that sugar can be won. The figures in the last column express the first point clearly and might rule out, *e.g.* M.36, which, though a good cane in other respects, would cost too much to handle.

The ease with which the sugar can be obtained is largely but not entirely a factor of the purity, and this has been already allowed for by the use of Winter's factor for calculating the yields of sugar. These are based on analyses kindly undertaken by the Sugar Technology Department for the College which made special arrangements to obtain running samples while the canes were being milled in the College Experimental Factory. It was not possible always to arrange separate samples from each plot, and in one year no sampling at all was done. That the figures above are however a fair representation of the quality of these canes may be taken as certain.

But it is not entirely a matter of juice purity; there may be other qualities in the juice which affect its behaviour in the boiling house. The most disappointing cane in this respect is P.O.J. 2878 which possesses a refractory habit that makes it very difficult to clarify, for apart from this drawback, the sugar yield is astonishing. Similar difficulties are experienced in other countries. The situation in Cuba with reference to this cane is described as Agriculture *vs.* Chemistry.* As far as Trinidad is concerned, chemistry has won, for this cane has almost entirely dropped out of cultivation, though it may yet be worth while to consider its possibilities with properly regulated field operations and appropriate mechanical and chemical measures in the factory.

The experiment has shown that Uba is definitely a poor cane in its class, and that three of the thin canes under trial are superior to it, namely Co.213, M.36 and Co.281. The first of these is already grown on a fair scale in Trinidad. It is reported by the Sugar Technologist to be a fairly good milling cane. M.36 is tough and consequently a bad miller, but a fair field cane and reasonably easy to harvest. Co.213 is a good steady yielder but not an easy cane to cut, being very thin and rather trashy. The trash would not be a serious trouble in conditions where burning was possible, but these plots had to be cut a few at a time for analytical purposes, and could not be burnt. It is for this reason that no figures of costs are given.

The statistical examination of the results is of some interest, for the continuation of the crop for six harvests enables account to be taken of the influence of the season on the results. The analysis of variance is given below:

Acknowledgments.

Much of the experimental data has been collected and arranged by students of the College, notably Messrs. O. S. Milburn, A. V. Coombs, P. A. Chan Choong, and H. M. James.

* "The Chemistry *vs.* the Agriculture of P.O.J. 2878" *Supplement* 8th *Conf. Assn. Technicos Azuc. Cuba,* 1935. (abstracted in *Int. Sugar Jl.* 37, 447).

Analysis of Variance.

Factor.	D.F.	S.S.	Variance.	Remarks.
Total: all plots in all seasons	167	1067852		
Main units: total for 28 plots irrespective of season	27	458715		
Varieties	**6**	**421459**	**7.0243**	Significant.
Blocks	**3**	**.5118**	**.1706**	
Error (a)	**18**	**3.2138**	**.1785**	
Seasons	5	42.9658	8.5931	Significant.
Interactions: Seasons × Variety	30	11.6142	.36047	Significant.
Interactions: Seasons × Blocks	15	7998	.0533	
Error (b)	90	55339	.06149	

OBSERVATIONS ON WILD COTTON IN BIRDS' NESTS IN ANTIGUA.

By Harold E. Box, F.R.E.S.

The following notes are submitted for publication in the belief that they may be of interest and even importance to the general ecology of West Indian cotton pests and also as they may throw some light on the question of the survival of certain insects, *e.g.* the Pink Bollworm (*Pectinophora gossypiella* Saunders) during the Close Season in Antigua, and possibly elsewhere.

The uncultivated bushlands of Antigua vary in character from a rather open type of thorn-scrub pasture resembling orchard savannah, dominated by "Cossie" (*Acacia nilotica* Delile,* *A. lutea* Hitchc., *A. farnesiana* W.), or Logwood (*Haematoxylon campechianum* L.), through closed thickets of Wild Tamarind (*Leucaena glauca* Benth.) to a secondary climax type of thick xerophytic bush with fairly large trees, *e.g.* Loblolly (*Pisonia subcordata* Sw.), Turpentine (*Bursera simaruba* Sarg.) and White Cedar (*Tecoma leucoxylon* Mart.) occasional to frequent. Generally speaking the rainfall increases from an annual average of less than 35 inches in the north and east to well over 50 inches in the south-west; the mesophytic character of the south-western part of the Island is indicated by the presence of numerous shrubs of the families Myrtaceae, Piperaceae and Melastomaceae. The lower reaches of the numerous streams or "ghauts" form a characteristic zone, of which the Whitewood (*Bucida buceras* L.) is the best indicator, with abundant Manchineel (*Hippomane mancinella* L.) in the more saline parts.

Such areas cover in their aggregate hardly less than one-half of the island's total area, or about 30,000 acres, and constitute the regular breeding places of two of the commonest and numerically the most abundant resident birds of Antigua, viz., the Golden Warbler [*Dendroica petechia bartholemica* (Sundevall)] and the Yellow-breasted Honey Creeper [*Coereba dominicana* (Taylor)].

Throughout the earlier months of the year, from February until June, the nests of these birds especially the *Coereba*, are to be found without difficulty, located generally on a branch, or between two branches, of a shrub or small tree, about 8 to 15 feet above the ground, but other habitats are not at all unusual. The nest of *Dendroica* is an open cup-shaped structure, circular in outline and about 5 or 6 inches in outside diameter. *Coereba*, on the other hand, constructs a comparatively large dome-shaped nest, totally enclosed except for a small orifice in one side; nests of *Coereba* are seldom less than 7 inches in height and may reach well over 12 inches. The materials of which these nests are composed are grasses and sedges, cane trash, small twigs, vegetable fibres, as well as dry leaves, feathers, &c., but large quantities of the lint and seeds of Wild Cotton* enter into their outside construction, apparently for ornament. Some nests have been found which are veritable balls of this material with only a slight inner lining of grass, &c., (Figs. 1 and 2).

These "cotton" nests have been observed everywhere in uncultivated bushlands throughout the island, often in abundance; occasionally several may be in sight from a single point of observation. One afternoon's collecting on the part of three small boys yielded thirty-five nests from a few acres along a narrow belt of bush bordering a stream near the Sugar Factory, and even so there were many other nests so situated that the boys failed to secure them.

Wherever these nests have been examined the cotton has proven to be of the wild perennial types, and so far no Sea Island Cotton (*G. barbadense* L.) has been noted as being used by the birds, even where it is cultivated nearby. The facility with which the birds are able to secure large quantities of the material over such a wide territory provides ample evidence of the abundance of Wild Cotton in these types of bushland in Antigua. The eradication of the plant from these situations in competition with such regular and fertile sources of re-infestation becomes therefore a matter of considerable difficulty.

A few typical *Coereba* nests have been examined† in detail and the following data have been secured:—The weight of six nests varied from 8.37 gr. to 41.27 gr. per nest (average 29.88 gr.); the weight of cotton (seeds plus lint) per nest varied from 4.227 gr. to 21.243 gr. (average 13.494 gr.); and the percentage of cotton in the total nest material (by weight) varied from 27.9 per cent. to 54.6 per cent. (average 45.2 per cent.). The number of cotton seeds present varied from 19 to 268, with an average of 165 seeds per nest. These figures

*Botanical nomenclature adopted from *Flora of Jamaica*, by W. Fawcett and A. B. Rendle, published by the British Museum (Natural History), London.

*The perennial wild cottons (*Gossypium*) of Antigua have not been determined specifically. They evidently belong to the group which Harland (*West Indian Bulletin*, XVIII, 1920, p. 13) classifies as the *purpurascens-vitifolium* series. Seeds from birds' nests represent at least two distinct forms, in one of which the fuzz covers the entire seed, and in the other the apical portion only. Ecologically Wild Cotton may be regarded as an occasional to frequent constituent of uncultivated bushlands as defined above.

†By Mr. C. A. Gomez, Agricultural Development Officer, Antigua, who has been kind enough to furnish me with the figures that follow.

WILD COTTON IN BIRDS NESTS IN ANTIGUA.

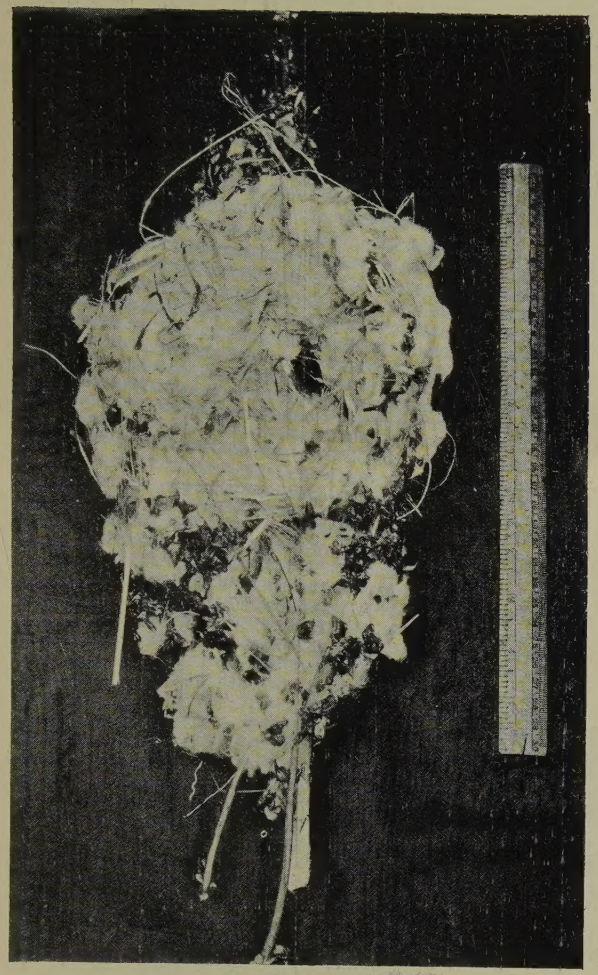

FIG. 1.—A large nest of *Coereba* on stalk of *Malachra capitata* in *Bucida buceras* association. North Sound, May, 1937.

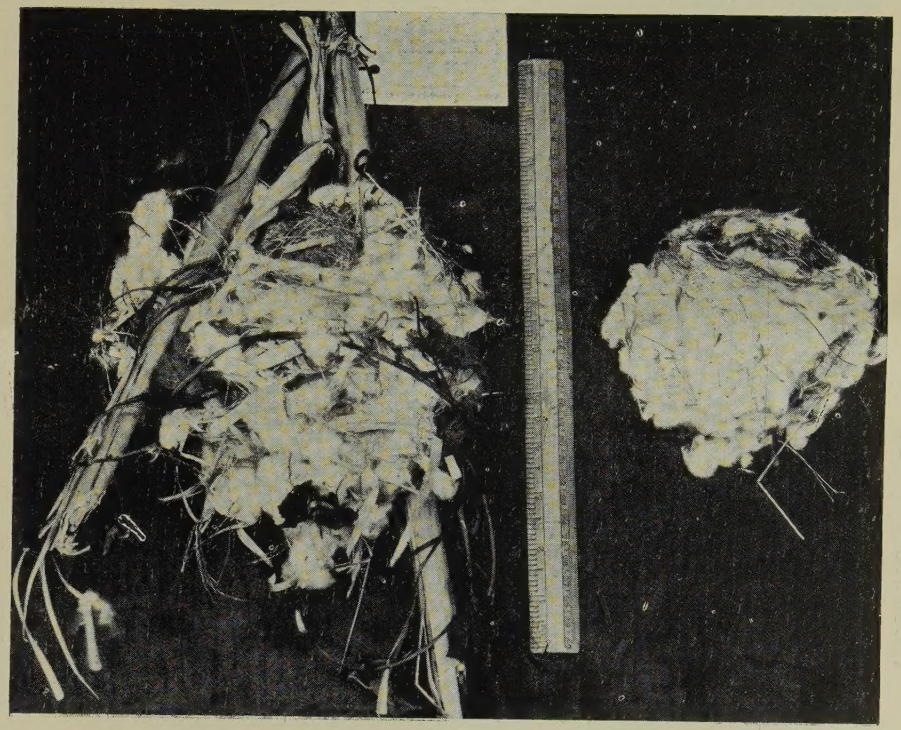

FIG. 2.—*Left.*—Nest of *Coereba* on a broken cane-arrow on edge of a canefield bordering *Haematoxylon* thicket. Cassada Garden, April, 1937.
Right.—Nest of *Dendroica* from *Acacia* bush. North Sound, May, 1937.

GUMMOSIS OF CITRUS IN TRINIDAD.

FIG. 1.—Marsh grapefruit tree, 15 years old, from which the low branches have been removed. Although the shape of this tree is poor, inspection of the trunk for gummosis is now possible, and light and air are admitted.

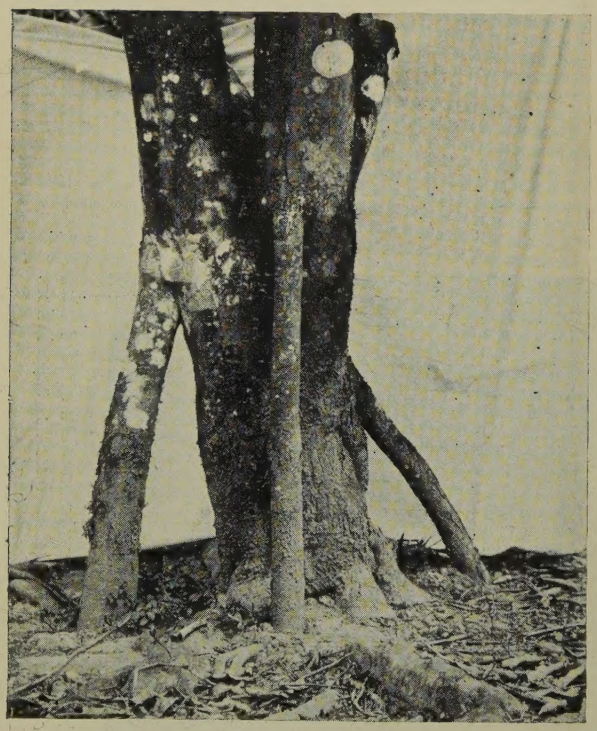

FIG. 2.—Marsh grapefruit tree severely attacked by gummosis inarched three times with sour orange seedlings.

FIG. 3.—Marsh grapefruit tree attacked some years ago by gummosis but saved by inarching. Note that the original trunk has disappeared and the tree now stands on the four sour orange inarches.

represent average nests and do not include large examples such as that illustrated in Fig. 1, in which there are probably over 500 cotton seeds. So far no nests of *Dendroica* have been examined in detail. They are smaller than those of *Coereba* but it is probable that the percentage of cotton in them is higher.

The cotton seeds found in these nests are viable except where injured by insect attack. In the course of the examinations a number of hollowed-out seeds were found linked together in pairs with the resting stage larvae of the Pink Bollworm inside; in one nest an active larva was found among the lint. These nests were collected two weeks after the Close Season had been declared in Antigua.

In the field it is not uncommon to find numbers of nymphal and adult Cotton Stainers (*Dysdercus andreae* L.) on the cotton nests, even where no living food-plants of these insects occur in the vicinity.

It is clear that the nests of *Coereba* and *Dendroica* become veritable sanctuaries for carrying over the Pink Bollworm during the Close Season in Antigua, for the peak of the nest-building period occurs at a time when the Wild Cotton is most heavily infested. Further detailed investigations of the subject are required, since both genera of birds have a wide distribution in the West Indian area and may have similar habits elsewhere. It also seems desirable to determine to what extent other birds utilise cotton in the construction of their nests. I have one record of a few seeds of Wild Cotton in an old (?last season's)nest of a native Hummingbird (species uncertain) found at Pearn Hill, near York's, on 9th May, 1937.

GUMMOSIS OF CITRUS IN TRINIDAD.

III.—Notes on the Control of the Disease in Old Plantations.

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In the first paper of this series (1) it was suggested that it might be possible to prolong the life of misshapen and diseased grapefruit trees for a few years while a replanting scheme was being carried out or while young fields were coming into bearing. The recommendations for bringing this about included attention to drainage, more frequent brushing and round-weeding, trimming of low branches, inarching, and frequent inspection of the trees accompanied by the careful excision of any diseased bark* found. Since there were still many fields in Trinidad in which the trees were of an unsatisfactory type not calculated to resist gummosis (*i.e.*, low budded, low planted, low branching, and insufficiently trimmed) it seemed desirable to test these recommendations experimentally.

In March 1934, therefore, a field of approximately ten acres which had originally contained 572 Marsh grapefruit trees was selected for observation. This field is on the northern side of the Central Range near Mount Tamana, subjected to a heavy rainfall of around 100 inches per annum, on a heavy acid clay soil where conditions are generally calculated to be favourable to gummosis disease.

The field is the oldest commercial grapefruit plantation in the island; some trees being twelve years old in 1934, others two or three years younger. Almost without exception these trees were low-budded, allowed to branch too low, planted too low, and had low branches reaching the ground excluding the light and creating a humid atmosphere near the trunks. There was every indication that gummosis disease had already obtained a firm hold and that unless drastic control measures were immediately initiated many of the trees would be dead within the next few years.

A survey of the 572 trees showed that 162, or 28 per cent. were attacked by gummosis disease to a greater or a lesser extent, and that 39 trees had already died. It was impossible to determine the cause of death of these 39 trees, but it seemed highly probable that most of them had died of gummosis.

Control measures were then undertaken. The trees were drastically pruned, in some instances nearly half the tree was cut away and branches up to six inches in diameter were removed. Trimming was continued until there was no foliage within five or six feet of the ground and it was possible to pass freely under the tree to inspect the trunk (fig. 1). No dressing such as Stockholm tar was used on the cut branches which after three years are still in a satisfactory condition. Callus has formed extensively and the smaller cuts are completely healed. Next, the diseased trees were treated. All diseased bark was carefully excised until clean healthy tissues could be seen all round the lesions. This is an operation which must be performed exceedingly carefully if it is to be successful, since the smallest piece of diseased tissue left will allow the disease to spread. No attempt was made to collect and destroy the material excised since the organism causing gummosis disease, *Phytophthora parasitica*, is a common soil fungus and is probably universally present in the soils of Trinidad grapefruit fields. No fungicide or protective dressing was applied to the wounds, some of which were very large, between two and

*Where 'bark' is mentioned in this paper it is all the tissues outside the cambium which are referred to; *i.e.*, the cortex.

three square feet of bark having been removed in extreme cases. The operation was performed at the height of the dry season and the wounds were simply left to dry and heal exposed to the sun and wind. The author does not wish to dissuade planters from using Bordeaux paste or from applying dressings to wounds. The object of the experiment was merely to see if grapefruit trees could be treated for gummosis without their use. Under the conditions of this experiment it is obvious that they can be dispensed with, but in wetter areas or during the wet season it may be advisable to use Bordeaux paste followed by Stockholm tar or some other such dressing. Furthermore it is easier to inspect wounds which have not been treated in this way to see if the control measures have been successful or if the disease is still spreading.

The drains in this field require opening once every three or four years, and were done in 1934 at the same time as the gummosis control was started. One more brushing* and one additional round-weeding,* making four of each per annum have been given since 1934. The cost of the heavy trimming was approximately ten cents per tree and the cost of the extra round-weeding and brushing was four cents per tree per annum. An initial expenditure of about $5.00 per acre for trimming, and an annual expenditure of $2.00 per acre for the extra round-weeding and brushing is a small price to pay for the safeguarding of trees capable of producing up to ten boxes of fruit each per annum. Only slight additional trimmings have been necessary during the last three years.

The field was resurveyed in March 1935, May 1936 and April 1937, with the results shown in Table I. The following points from the table are worthy of note. The number of diseased trees with active gummosis has fallen from 162 in March 1934, 64 in March 1936, 50 in May 1936 to 32 in April 1937. The death-rate has fallen, 39 trees died prior to 1934, 16 in 1934-35, five in 1935-36, one in 1936-37. By April, 1937, the disease had been successfully arrested in 122 trees, and, of the 162 trees treated in 1934, 80 have never been attacked since. Of these 162 trees 44 were more than two thirds ringed by the disease and the writer's experience of gummosis in this field indicates that if these had been left untreated they would all have been dead within two years, whereas now 25 of them are still living and giving good crops of fruit.

Table I.

	Healthy.		Diseased.			
	Never Attacked.	Complete Recovery.	Treatment Successful, *i.e.*, Disease Arrested.	Disease Spreading.	Total Deaths.	Total New Attacks.
1934	371	—	—	162	39†	—
1935	365	6	82	53	55	11
1936	352	15	95	39	60	22
1937	336	21	122	16	61	38

*In Trinidad grapefruit fields the soil is generally kept clean weeded to the full extent of the branches of the trees, and the grass and weeds in between the trees merely cut short. Cover crops are not grown and no intercultivation of the soil is practised.

† Dead prior to March, 1934.

Previous to 1934 diseased trees had been inarched from time to time with beneficial results (fig. 2). In June 1934, therefore, provision was made for inarching all the diseased trees, and now the majority of trees which had been attacked have 2, 3, or 4 sour orange plants of varying sizes and ages inarched on to them. While the benefit derived from inarching trees but slightly attacked is questionable, there can be no doubt that many of the more seriously attacked trees have been saved in this way. Fig. 3 shows a tree attacked by gummosis some years ago from which the original root system has completely disappeared, so that it now stands upon the four sour orange plants inarched on to it when the attack was first noticed.

In 1935, the year after the severe trimming was given, the 15-acre field in which the experimental block is situated gave a record yield of 5,630 field boxes of fruit. It must be remembered that the year 1934-35 was a record one for Trinidad grapefruit and that the high figure of 5,630 field boxes is not *due* to the trimming, but in spite of it. If the trees had not been trimmed the yield would probably have exceeded 6,000 boxes, but this yield would probably have involved the loss of some of the trees.

All trees receive a heavy dressing of artificial manures every year; the amount given to each tree has not been altered to any large extent during the past four years.

Most of the dead trees in this field have been replaced with young high-budded trees calculated to resist gummosis and some of these are now coming into bearing. The whole field is in a better condition than it was in 1934 and is capable of giving higher yields. If this treatment is continued there is every reason to suppose that the trees will survive and yield good crops for many years to come. There can be no doubt therefore that gummosis disease can be controlled under Trinidad conditions even on trees of this type and it is to be expected that there will be little trouble experienced with trees worked high on sour-orange stock, such as have been planted on the majority of estates in Trinidad for the last five years or more.

My thanks are due to Mr. W. S. E. Barnardo for allowing the experiment to be carried out on his estate and for the help which he has always given me in this work.

Reference.

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NOTES ON CERCOSPORA LEAF SPOT OF BANANAS (*Cercospora musae*).

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Introduction.

The *Cercospora* leaf spot (*Cercospora musae* Zimm.) of bananas is now causing considerable damage in Surinam especially on the empoldered plantations along the lower Surinam and Commewijne-rivers. As a rule the first crop of fruit is good or fairly good, but the second and especially subsequent crops are considerably reduced. On the pegasse soils near the coast, however, fruit production is much better. These young fluviomarine clay soils covered by a herbaceous swamp flora of *Typha, Scirpus, Ischnosiphon* and other aquatic plants after empoldering give high yields of Congo bananas even after four years. This is shown clearly on the Congo banana experimental fields of the Surinam Banana Company. There, near the coast, the trade wind blows freely over the open savannas drying up the dew in the morning earlier than in the damp fields along the rivers which are surrounded by jungle and shade trees. The rainfall also is less along the coast. Therefore, leaf disease causes less trouble on the pegasse soils than elsewhere in Surinam, but even here the application of Bordeaux mixture twice a year has been attended with remarkably beneficial results.

Occurrence.

From 1908-1914 Gros Michel and Congo bananas were planted in Surinam on a commercial scale; no troublesome leaf diseases were observed until 1933 and 1934 when *Cercospora* leaf spot as well as the *Helminthosporium-Cordana* leaf disease suddenly appeared in the banana fields (5). In 1933, *Cercospora* leaf spot was observed in Trinidad by Wardlaw (8)—the first report of this disease in the Caribbean region—and in 1935 Martyn (2) recorded sporadic cases in Demerara. It seems evident therefore that leaf spot has been introduced into the West Indies in recent years, possibly through the introduction of planting material. In 1936 the disease began to spread rapidly over the Caribbean banana area, especially Central America and Jamaica.

Cercospora musae was first described in 1902 by Zimmermann in Buitenzorg, Java (10), but up to the present has been of no importance in the Netherlands East Indies. Mr. J. S. C. Kasteleyn, Director of the Surinam Banana Company in Holland, after seeing the ravages of this disease in Surinam in 1934, visited Java and Sumatra and looked out for banana leaf spot there. He could not, however, find the spots other than very sporadically and was informed by phytopathological authorities that *Cercospora* is harmless to bananas in the Netherlands East Indies. In Ceylon also it seems to be of no importance.

In 1913 Campbell (1) mentions *Cercospora* leaf spot to be very troublesome in Fiji and in 1925 heavy losses from this disease were reported by Simmonds (6) from Queensland, Australia.

Symptoms.

The symptoms of *Cercospora* leaf spot have already been described by Campbell (1), Simmonds (6) and Wardlaw (8), and their descriptions may be supplemented here by some further observations.

In Surinam the two youngest leaves of an actively growing banana plant never show *Cercospora* spots. In Australia according to Simmonds (7), the first leaves also remain unaffected by leaf spot. On the third leaf, however, the primary streak and the first brown spot stage appears. On quick growing, well manured and well watered plants, the first brown spot stage may not be found before the fourth leaf, whereas on weak and slow growing bananas the spots are already visible on the second leaf. On fruiting plants even the last and youngest leaf may be spotted. On older leaves the centres of the spots successively dry out and turn light grey, sometimes light brown (fig. 20).

Campbell (1) and Simmonds (6) mention small yellow green streaks 5 to 10 mm. long and 1 mm. broad as the earliest symptoms. On artificially but also on naturally heavily infected leaves in the field it is not difficult to see the very first symptoms as minute yellow green speckles of about the size of an air chamber (fig. 14). In a few days these speckles grow into the typical, easily visible streaks (fig. 15) which at first are pure yellow green, but when full grown, look as if covered with rust. If observed in the early morning when the leaves are still covered with dew, the leaf tissue around many of the rusty streaks appears to be infiltrated with water (figs. 23 and 24). A part of this infiltrated leaf tissue at a distance of 1 to 3 mm. around the primary streaks dies the same day and turns brown. These spots may still enlarge somewhat by infiltration during the following night, but further extension is arrested by the formation of a broad black margin of leaf tissue impregnated with a dark red or black gum. Streaks that do not become infiltrated remain in a non-necrotic stage without fructifications.

In order to study the changes which take place between the streak and brown spot stages three leaves with many full grown streaks of apparently the same age were selected. A section of the leaf containing only mature streaks without brown spots was marked and the position of the streaks was carefully noted in a sketch. Each day at 7 a.m. the leaves were examined and the infiltrated streaks recorded in the sketch.

The following results were obtained.

Leaf.	Date.								
	Feb 26	Feb 27	Feb 28	Feb 29	Mch 1	Mch 2	Mch 3	Mch 4	Mch 6
	Number of Primary Streaks.	Percentage of Infiltrated Streaks and Brown Spots.							
		%	%	%	%	%	%	%	%
A	173	—	1	5	28	68	73	84	92
B	214	—	4	7	15	35	43	53	60
C	332	1	7	23	40	74	82	91	94

In a week's time, thus, most of the streaks had turned into brown spots.

It seemed probable that the infiltration was caused by the penetration of dew through the dead stomata of the streak into the air chambers. To demonstrate this the three youngest leaves of a Congo banana were infected with *Cercospora* conidia and the plant placed in a big wooden box (with ¾ cubic metres of well manured soil) which was fixed on a low truck on rails. When the streaks appeared on the leaves, the whole plant was pushed under a large glass roof where no dew could be formed. The soil was watered daily.

There was no formation of dew on the leaves under the roof but a profuse guttation of water along the entire edges of the leaves. This water fell on certain parts of the lower leaves and it was very surprising to find that even outside those parts the mature streaks after one or two days were infiltrated by water exactly in the same way as when covered by dew. In the early morning these infiltrated spots were covered on the upper as well as on the lower side of the leaf with large drops of guttation water. Infiltration begins as early as 8 or 9 p.m. when small trickles of water are visible on the infiltrated parts of the leaf.

Thus the typical infiltration of the leaf tissue surrounding the streaks is not the result of an imbibition of the air chambers by dew but of an internal guttation process, caused apparently by a poisoning effect of the *Cercospora* fungus.

The chief damage caused by this disease is the premature dying of considerable areas of the leaf thereby bringing about a reduction in the assimilating surface of the plant. A healthy, actively growing Congo plant has at one time from ten to 14 green leaves. In badly spotted fields only four to six living leaves per plant may be counted. The average number of living leaves therefore is a valuable index of the condition of an infected banana field.

The total leaf surface killed by the direct action of *Cercospora* may be less than ten per cent. in most cases, but the vascular bundles in the spots are destroyed as well. In the parallel nerved banana leaves therefore every spot cuts off the communication with the distal part of the bundles. It is true that there are at intervals of ¾ mm. anastomoses between the vascular bundles containing only one small water vessel, but these communications prove insufficient for the normal life of the distal parts of the leaf if the blade is heavily spotted. Large sections or the whole, of such leaves, can be killed in a few days (fig. 17).

If the spotting is less severe the entire leaf may turn yellow green and die more or less prematurely.

The Fungus in Pure Culture.

Cercospora musae is easily isolated from conidia, as shown by Campbell (1) and Simmonds (6). It grows very slowly and compactly and it is only after six to eight days that minute black mycelia become visible on the agar plates. Big pseudoparenchymatous masses are formed after several weeks on sterilised carrot and on aseptically collected bananas. On bananas, especially, the hard, black stromata are covered with an abundance of pycnidia—or perithecia-like bodies (fig. 23), filled with a fine hyaline mycelium. They have never been found, however, to contain asci, conidia or spermatia. Plenty of these bodies are also formed on sterilised banana leaves inoculated with *Cercospora* mycelium where they are found partly in pseudoparenchymatic structures or partly as isolated bodies in the leaf tissue. There were never any signs of an ostiole nor of any kind of spores.

The following method was tried to induce the fungus to form perithecia. Since the fungus may possibly lose its capacity for forming perithecia when cultivated on agar, it was grown on green living leaves covered with primary streaks. After a thorough cleaning with a rubber sponge and a rinsing in tap water, the leaf was left in a solution of 0.2 per cent. sublimate for 20 minutes. Then after further rinsing and thorough washing in sterilised water it was cut into pieces under strictly aseptic conditions. Some of these pieces were placed immediately in long culture tubes and fixed in the upper dry part of the tube so that they could be moistened with the sterile water present in the lower part and dried without the cotton plug having to be removed. The other pieces were first placed for three days on Sabouraud-agar slants. When the *Cercospora* mycelium began to grow out in the agar, the pieces, still green and living, were brought into the culture tubes described above. Of the pieces only about 20 per cent. proved to be contaminated. For four to six weeks they were alternately moistened and dried after which they were embedded in paraffin. The sections revealed plenty of *Cercospora* acervuli producing normal or nearly normal conidia and also typical spermogonia with spermatia, but there were no perithecia.

These experiments thus prove conclusively that the spermogonia, constantly present on the dry spots, belong to the life cycle of *Cercospora musae*.

Fungal Flora of the Dry Centres of Cercospora Spots.

On the dry centres of *Cercospora* spots the same 5 fungus-fructifications are found not only here in Surinam but also in Australia (Simmonds (6) and Parham (11)). Most numerous are the acervuli of *Cercospora* which on the dry centres are chiefly found on the upper side of the leaf. On the primary brown spots, however, the conidia are produced most abundantly by the many small acervuli on the lower side, but afterwards they do not develop further and most of them disappear when the spot collapses, whereas on the upper side, they grow out to permanent stromatic bodies (figs. 4 and 5), producing conidia all the time. Through a magnifying-glass they appear in straight rows parallel to the nerves as minute black dots.

Campbell (1) states that the acervuli "break through the epidermis". This was never observed. Without exception the acervuli develop in the small substomatal air chambers and the conidiophores grow through the pores to the surface (fig. 10). More and more conidiophores use the same way compressing and tearing the guard cells. On the dry spots these cells become invisible. Sometimes the whole stomatal apparatus is lifted by the growing acervulus and the remains are found later between the conidiophores.

The surface of an old acervulus is more or less cushion like (fig. 5). The remnants of the basal part of the old dead conidiophores form a palisade-like superficial cover. It seems, therefore, that the new conidiophores are endogenous in origin. On old acervuli they project only ten to 20μ above the surface of the palisade layer.

The conidia are produced only when the leaf is covered with a film of water as generally happens with dew. Also a long continued drizzle may favour their development. If, however, dew formation is prevented by a cloudy night or by wind, few or no conidia are produced.

On the dry spots spermogonia are also found regularly (fig. 1). In the preparations of whole dry centres, bleached for 1½ to two days in a chromic-acetic-acid solution and cleared in xylol, it will be easily seen that all the spermogonia originate in the substomatal air chambers in the same way as the *Cercospora* acervuli. They open immediately under the widely opened stomatal pores. The same pore is sometimes used by an acervulus. Their walls consist of one or two layers of flat dark polygonal cells. The average diameter of a spermogonium is about 50μ, but the biggest measure 90μ. The spermatia which measure 0.8 × 3.5 – 4μ are formed in long straight chains. Germinating spermatia were never seen. Spermogonia are less frequent than acervuli and sometimes grow gregariously intermixed with *Cercospora* acervuli.

Two kinds of perithecia are constantly found on the spots. Most common are the perithecia of a *Leptosphaeria* (fig. 4) with 3-septate spores found equally frequently on both sides of the leaf. The perithecia remain immersed in the leaf tissue and it is only the ostiole which reaches the surface by way of the widely opened stomatal pore. In the xylol preparations of dry spots already described the perithecia appear to be arranged irregularly, sometimes gregariously, sometimes in short rows, or more or less evenly distributed. The average diameter of a perithecium is 85μ, but the largest measured had a diameter of 155μ. In the xylol preparations the asci may easily be counted in the optical section. The biggest perithecia contain 80 to 100 asci, but commonly only 30 to 50 are present. The asci measure 50 to 55 × 7 to 9μ, and the spores 20 to 22 × 5μ. The numerous paraphyses are very thin, less than 1μ in diameter and longer than the asci. Just ejaculated spores are light brown, but if encountered accidentally while examining the leaf surface under the microscope they appear very dark brown.

Probably this fungus is identical with *Leptosphaeria musarum* Sacc. et Berl. but it is impossible to prove this conclusively without a careful comparison of herbarium material and cultures of the two fungi.

The other kind of perithecia belongs to the genus *Mycosphaerella* (fig. 2). These bodies are exceedingly small, even smaller than the spermogonia described above. They are less frequent than *Leptosphaeria* but constantly present. The diameter is only 25 to 37μ (average 31). These minute perithecia contain only one to two asci measuring 24 to 28 × 10 to 12μ and two-celled hyaline spores 20 to 22 × 5 to 6μ. They are slightly constricted near the septum. Exposed for several days to the air the spores turn dark brown. The ostiole reaches the surface by way of the stomatal pore, often together with a *Cercospora* acervulus. The walls of the *Mycosphaerella* perithecia are bleached very easily in chromic-acetic-acid. It is therefore impossible to find the perithecia in xylol preparations with low power objectives. With high power systems, however, if the lens is focussed on the lower part of the water cells the perithecia are easily found because the one or two asci are conspicuous in the optical section. In the xylol preparations only two perithecia were found with three asci, two of normal size and one as a small developing ascus. All others had only one or two asci. This *Mycosphaerella* is very distinct from *Mycosphaerella musae* (Speg.) Syd. and may be regarded as a new species. In view of the fact that the species name "musae" is already given to another *Mycosphaerella*, it is proposed to name this fungus *Mycosphaerella minima*.

There is still another fungus fructification which is constantly found on the spots, namely pycnidia of the genus *Hendersonia* (fig. 3). These pycnidia may be frequent on some spots but in most cases there are only one to three or they may be altogether absent The pycnidia are filled with large 5-celled pycnospores. Spores with four or six cells are rare. They are light olive green and measure 20 to 32 × 3 to 3.5μ. Old spores found on the leaf surface are not much darker than those

that have just left the pycnidium. The diameter of the pycnidia is 65 to 132μ (average 80μ). The pore is 4 to 5μ wide and lies on a small black papilla which apparently breaks through the epidermis without making use of the stomata.

Simmonds mentions having seen 3- and 5-septate *Leptosphaeria* spores. I am of the opinion that the 5-septate spores may also be formed in Queensland in pycnidia and not in perithecia. Here in Surinam, the 4-septate spores are prevalent, in Australia apparently the 5-septate.

Genetic Relationship of Fungal Fructifications.

As described above, repeated attempts to produce the perfect stage of *Cercospora musae* in pure cultures were not successful. These experiments showed, however, that the spermogonia belong to the *Cercospora* fungus.

The easiest way to demonstrate a possible relation between the different fungus fructifications is to cultivate mycelia from the different spores and compare them.

Hendersonia spores may easily be isolated. Pieces of banana leaves about $1\frac{1}{2} \times 1\frac{1}{2}$ cm. each, with a *Cercospora* spot in the centre, were placed on a sterilized cover glass, the lower side uppermost after being thoroughly washed and dried. One or two drops of sterile water were added on to the dry spot, care being taken that none could penetrate between leaf and cover glass. The whole was then placed in a moist glass chamber and after 12 hours the cover glasses were examined. On some, large brown masses of *Hendersonia* spores were found containing sometimes hundreds of conidia held together by a mucilaginous substance. When such a mass was found at a suitable distance from adjoining groups of ascospores, a minute drop of sterile water was placed on the *Hendersonia* spores with a platinum needle and stirred thoroughly. Then, with the aid of a sterile micropipette, the spores were transferred to sterile dilution water, inoculated into melted agar and poured into Petri dishes. In one day, without exception, all the dishes were covered with large quantities of identical mycelium. These colonies which grow fairly rapidly are covered with a greyish velvety aerial mycelium.

On most cover glasses several groups of a hundred or more *Leptosphaeria* spores were observed. The groups of *Mycosphaerella* spores however, were very small and contained only 8 to 16 spores.

On over 200 cover glasses examined no *Cercospora* conidia were found although living acervuli were present on every spot. As mentioned above *Cercospora* conidia are never formed in moist air alone, but only in a film of water.

Using the same technique an attempt was made to isolate the ascospores of *Leptosphaeria* but without success, even when the contents of the micropipette were brought directly into melted nutrient agar. Occasionally a few colonies appeared like those of *Hendersonia* but in most of the dishes they were absent. Similar attempts to isolate *Mycosphaerella* were unsuccessful, only several common saprophytic fungi appeared sporadically. This was explained as follows: when the contents of a micropipette taken from a group of *Leptosphaeria* spores were examined it was found that only a few whole spores were present besides many fragments of broken spores and that the ascospores were so firmly glued to the cover glass that they could not be removed without being damaged. In a drop of water on a micro slide the cover glass can be moved and pressed firmly without the spores being moved.

The technique was therefore modified as follows: instead of placing the leaf spots on cover glasses they were placed in a drop of water inside the cover of a Petri dish, where they were held in place by the cohesion of the water between glass and leaf. Nutrient agar had previously been poured in the bottom of the Petri dish. These dishes were left undisturbed for 12 hours and then the covers were changed with those of sterile dishes. In this way the *Hendersonia* spores which before had sometimes badly contaminated the heaps of ascospores, could entirely be excluded. Only the ejected spores of the two ascomycetes were present on the agar, easily visible under the microscope.

In 12 hours spores could be found in two-thirds of the dishes. About 20 per cent. of these dishes showed *Mycosphaerella* and others only *Leptosphaeria* spores. All dishes with both kinds of spores were discarded. The mycelia were later transferred into culture tubes and compared with cultures of *Hendersonia* and *Cercospora*.

The mycelia of *Hendersonia* and *Leptosphaeria* were identical. Even after some weeks there was no difference between cultures of different origin. Thus *Leptosphaeria* is not identical with *Cercospora* but with *Hendersonia*. This confirms the work of Simmonds in Queensland.

The mycelium of *Mycosphaerella* is hyaline at first but later turns brown. It grows slowly and in a twisted fashion. For comparison *Cercospora* cultures from different sources were used. *Cercospora* and *Mycosphaerella* mycelia grown on different substrata show some similarity, but in most cases the *Mycosphaerella* mycelia are markedly stronger and it is only on potato blocks that *Mycosphaerella* grows more slowly. For this reason it is not yet possible to conclude whether there is any genetic relationship between *Cercospora* and *Mycosphaerella*.

When it was found, however, that the perithecia of *Leptosphaeria* and the pycnidia of *Hendersonia* belonged to the same fungus it was believed that the *Mycosphaerella* perithecia might belong to the *Cercospora* fungus, since previous investigations on many other *Cercosporas* and *Mycosphaerellas* had proved that *Cercospora* conidia and spermogonia and *Mycosphaerella* perithecia are fructifications of the same fungus. This question is the more puzzling since the difference between the two mycelia is not great and chiefly quantitative. It does not seem impossible that further studies may show a genetic relationship between this *Cercospora* and *Mycosphaerella*.

Cultures of *Mycosphaerella*, *Cercospora*, *Leptosphaeria* and *Hendersonia* were sent to the

"Centraalbureau voor Schimmelcultures, Baarn, Holland," and are there at the disposal of mycologists for comparison.

Infection Experiments.

Our knowledge about the manner of infection of *Cercospora musae* so far is confined to the following statement by Simmonds (6) in 1933: "Infection was only obtained in the instances where the application of the spores was by means of spraying with or without subsequent bagging. In these cases typical lesions formed about four months after inoculation. These occurred on the portions inoculated from the upper and the lower surface, both sides of the leaf appearing to be equally susceptible to invasion". The passage "typical lesions formed about four months after inoculation" must undoubtedly be a mistake and the word "months" should be substituted by "weeks" since the life of a banana leaf probably never exceeds four months. An incubation period of four months is therefore impossible.

It requires a considerable amount of work to collect adequate quantities of *Cercospora* conidia for extensive infection experiments. In pure culture the fungus does not produce conidia and it is only on green leaves with primary streaks, washed and disinfected in corrosive sublimate that fairly normal conidia were grown in sterile culture tubes. This procedure is, however, very laborious and inconvenient for the collection of large quantities of conidia. The only suitable method for procuring the necessary infective material is to collect the conidia from fresh leaves. The most suitable time is early in the morning, when the leaves are still covered with dew, and the acervuli show plenty of conidia. Once the dew disappears, however, the large conidia are blown away.

As already mentioned, the lower surface of the primary brown spots is most prolific, because the number of acervuli here is about five times greater than on the upper surface of the leaf. These spots are found chiefly on the third and fourth leaves. The acervuli on the upper surfaces of the dry spots of older leaves produce a greater number of conidia per acervulus, but the total quantity of conidia is rather less.

The spotted leaves covered with dew were brought to the laboratory, cut into pieces of which 15 to 20 were temporarily placed on glass plates (13 × 18 cm.) under bell jars. It is best to collect the conidia from the spots when the dew is just disappearing and the turgid glistening conidia are easily visible. They are collected with a brush that is rinsed afterwards in a few cubic centimetres of distilled water. The water is then gently expressed from the brush into the container and the brush used again. This process is repeated until sufficient conidia are obtained. Generally, the conidia of three to four spotted leaves are enough for 10 infections.

This method proved unsuitable for infection experiments which had to be continued for several successive days, because there was not enough dew every morning. For such experiments spotted leaves collected during the day and stored on glass plates under the bell jars were used. About 60 such pieces were needed for 10 infections. If the air under these jars was merely saturated with water no conidia were produced. When, however, the leaves were sprayed and covered with a film of distilled water conidia were formed but not as readily as on freshly collected leaves. In this way, however, a daily supply of conidia was ensured.

Various methods of infection were tried. The only one that proved successful was the spraying of a suspension of conidia in water on the leaf as Simmonds (6) has done, but without any protection. After the spray dries up, even heavy rain will not wash away the conidia from the lower surface of the leaf. Other methods were tried, one of which was to place several drops of a suspension of conidia in water on the lower surface of the leaf and to cover this with a Petri dish for one day. The dish was carefully protected from the sun. When the streaks became visible, they were found situated in circles corresponding to the margins of the drops.

For the application of the spore suspension cardboard frames with slits 5 cm. wide were used, so that all infections were identical in size. The position of each infection was fixed by marks on the midrib. All infections were done on the Congo variety.

The first infection experiments were made on the lower surface of the first or second leaf, and the inoculated leaves were examined each day. On the 10th day small black dots became visible over the whole of the inoculated part of the leaf. These were entirely different from the yellow green speckles known as the first symptoms of the *Cercospora* disease. On the 15th day a few of the first *Cercospora* speckles appeared and on the 17th day the inoculated part of the leaf was speckled all over with minute yellow green spots (fig. 16). On the following days the speckles developed into streaks and on the 22nd to 24th days the streaks looked as if covered by rust. After 26 and 27 days a part of the streaks was already infiltrated (figs. 24 and 25), followed the same day by necrosis. Three or four days later or 30 days after the application of the *Cercospora* spore suspension (figs. 19, 21 and 22) the whole heavily infected area was brown and dead.

The black dots that appeared on the 10th day were caused by the leaf speckle fungus *Chloridium musae*. The leaves used for the collection of the infection material were partly covered with this fungus. Also at other times *Chloridium* speckles appeared repeatedly on the infected areas after 9 or 10 days, the incubation period of this fungus.

These inoculations were repeated 62 times on the lower surface of the leaf. The two youngest leaves that normally never show streaks or spots are by far the most susceptible to infection. Application of the same spore suspension produces much fewer streaks on the third leaf and a few streaks only, or none at all, on the fourth, fifth and the following leaves.

The infection of the fifth leaf illustrated in fig. 21 is one of the heaviest ever seen on a leaf of this age. The case depicted in fig. 22 (right) where the fourth leaf has remained free from spots even after heavy applications of conidia is common. The spots present on this leaf resulted from a natural infection when it was the first or second leaf.

The youngest leaf although still entirely rolled up is not less susceptible to infection than the first or second. The right side of the leaf (seen from the axis of the plant) is rolled up in the "tongue" 18 to 20 times and lies in the furrow of the midrib on the upper surface of the leaf. The left side of the leaf is rolled five times around the midrib and the right side of the leaf. The lower surface of the left side of the leaf therefore lies outside. The exposed part, a small margin on the left side, can easily be infected. Many of the leaves in the field show that the left margin, especially the distal part is black and dry (figs. 17 and 18).

When the tongue begins to unfold, the closed top breaks open and the left side of the leaf is loosened. At this stage, water with *Cercospora* conidia may penetrate through the layers of this side of the leaf forming heavily infected strips nearly parallel to the midrib (fig. 17, left). Water containing *Cercospora* conidia may also run down into the central hole of the inner right side of the leaf. At the bottom it penetrates between the layers of the rolled leaf and causes the typical heavily infected patches on the lower part of the right side of the leaf. This is frequently seen in heavily infected fields. These patches were repeatedly produced artificially by pouring a suspension of conidia into the central hole (fig. 18).

When the leaf unfolds further it does so more quickly at the top so that a steep funnel is formed. At this stage the lower surface of the right (inner) leaf blade touches in some places the upper surface of the nearly unfolded left blade. In these places the dew or rain water with *Cercospora* conidia is sometimes retained by capillary force even when the dew on the leaf has dried up. This results in heavily infected strips that run at an oblique angle with the midrib on the right side of the leaf (fig. 17 right).

Thus the oldest infection is manifested in the dead margin on the left side of the leaf. Next the straight strips on the left blade and the big dead patches on the lower right blade are formed. When the leaf has unfolded into a steep funnel, the oblique lines of spots so typical of the right blade of heavily infected full grown leaves are produced.

It will be obvious now why the streaks only appear on the third and the following leaves. A normal Congo plant in Surinam produces a new leaf at least every six to seven days. In Australia about the same time appears to be required since Simmonds (7) states that the first three leaves remain "unaffected". The tongue is accessible to a general infection about 3 days before it is fully unfolded. The third leaf therefore may have been infected 21 to 24 days before, which is the time needed for the streak—and first brown spot—stage to appear.

The well manured and well watered plants in the boxes on the trucks developed a new leaf every four and a half to five days. Here the streaks did not appear before the fourth leaf. Slow growing, weak plants on the other hand need eight and more days to produce a new leaf, with the result that the second leaf may be spotted. It is also obvious now why the last leaf of a fruiting plant is also spotted after a few weeks.

Sixty-four infections were made on the upper surface of banana leaves. Of these twelve were applied to bananas planted in big wooden boxes fixed on trucks, the others on unprotected plants in the field. When it rained the plants on the trucks were pushed under a glass roof, but otherwise they remained day and night in the open. Only seven of the 64 leaves infected on the upper surface produced a few spots, which undoubtedly originated from artificial infection (figs. 16 and 19). Of these seven, four appeared on the plants protected from rain.

As stated later the germ tubes of the *Cercospora* fungus enter the stomata. On Congo leaves 154 stomata per square millimetre were counted on the lower and 32 or about one-fifth of this number on the upper surfaces of the leaves. In every case, however, the number of streaks appearing on the upper surface was much less than one-fifth of the streaks on the lower surface of the same leaf, infected with the same suspension of conidia.

Plakidas (3) describes almost similar behaviour in the related *Mycosphaerella fragrariae*. This fungus enters the leaf through the stomata on the lower surface of the leaf. The "Klondike" variety of strawberry has also stomata on the upper surface but even after a heavy infection there are fewer leaf spots on the upper surface than might be anticipated from the ratio of stomata on the upper and lower surfaces of the leaf.

To determine the time that elapses between the application of the suspension of conidia and the entrance of the germ tube into the leaf a spore emulsion was sprayed in strips across the whole leaf.

For five or more successive days one strip was infected daily. Then the right side of the leaf was sprayed thoroughly with Bordeaux mixture on the lower surface. Four weeks later the treated strips on the left side of the leaf were heavily spotted or entirely necrotic, whereas on the right side, infection only took place when the fungicide was applied five to seven or more days after infection (fig. 22).

During the dry season, when the leaves are covered with dew nearly every night for 12 hours, the fungus begins to enter the leaf after five days. In the rainy season, however, when the covering with a film of water is shorter or less continuous, seven or eight days may elapse before the germ tube reaches the inside of the leaf.

Under the glass roof not a single *Cercospora* spot was formed after three weeks, even when the banana plants just outside the roof were

PLATE I

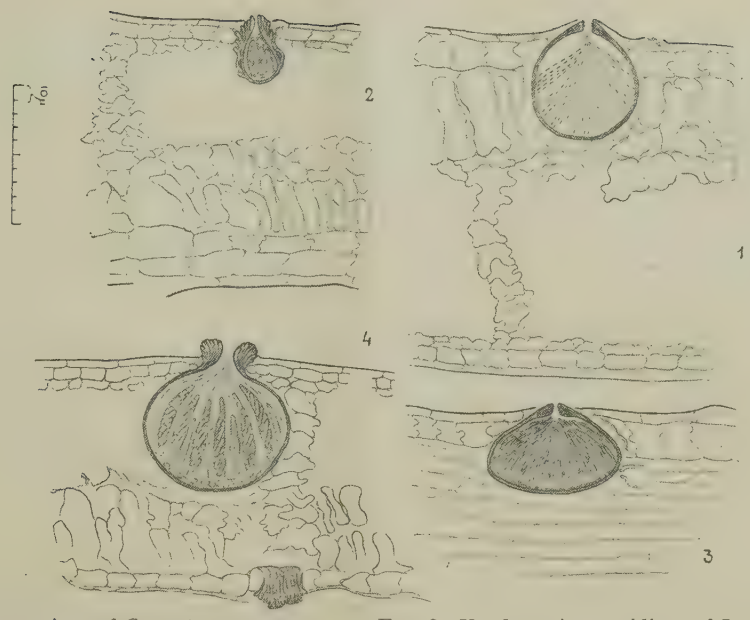


FIG. 1. Spermogonium of *Cercospora musae*.
FIG. 2. Perithecium of *Mycosphaerella minima*.
FIG. 3. *Hendersonia* pycnidium of *Leptosphaeria* sp.
FIG. 4. Perithecium of *Leptosphaeria* sp.

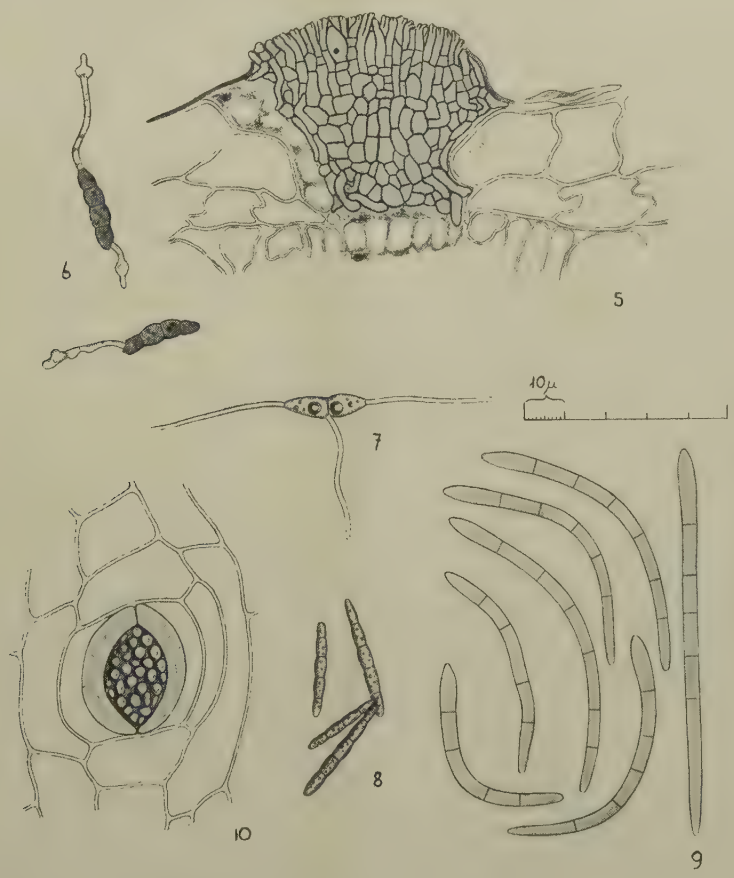
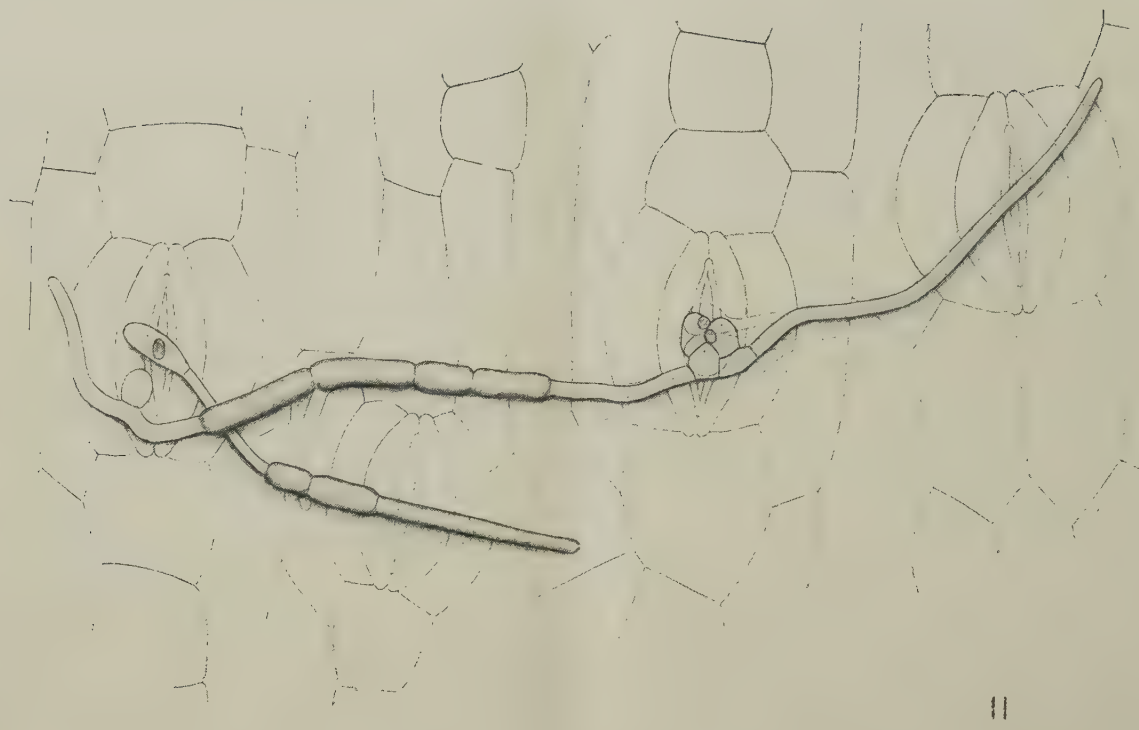


FIG. 5. *Cercospora* acervulus on upper side of dry centre.
FIG. 6. *Leptosphaeria* spores germinated on microslide.
FIG. 7. Germinated spore of *Mycosphaerella minima*.
FIG. 8. Spores of *Hendersonia* sp.
FIG. 9. Conidia of *Cercospora musae*.
FIG. 10. Stoma of recently killed spot with emerging acervulus.

PLATE II



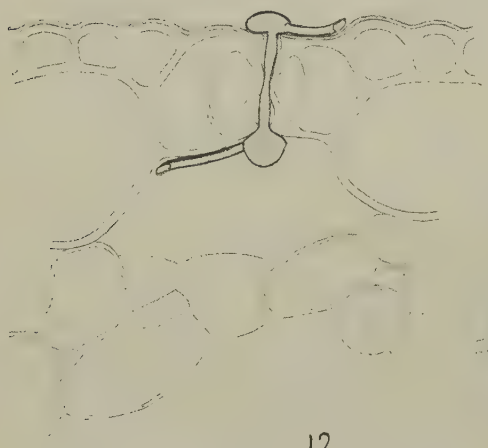


Fig. 11. Two germinated conidia with stomatopodia and substomatal vesicles.

Fig. 12. Stomatopodium and substomatal vesicle.

Fig. 13. Inside view of mesophyll with infection tube, substomatal vesicle and emptied conidium.

PLATE III

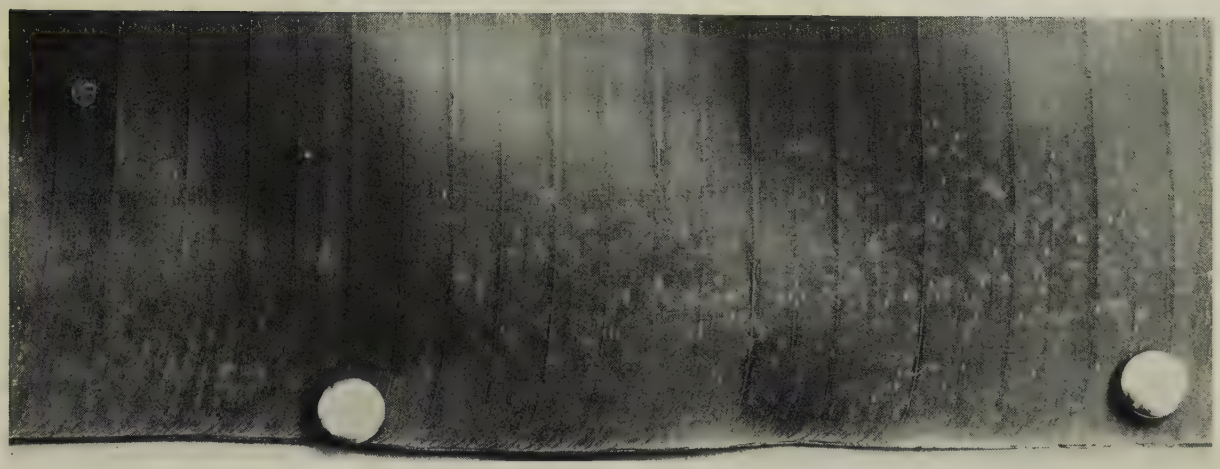


FIG. 14. Very first symptoms, fine yellow green speckles.

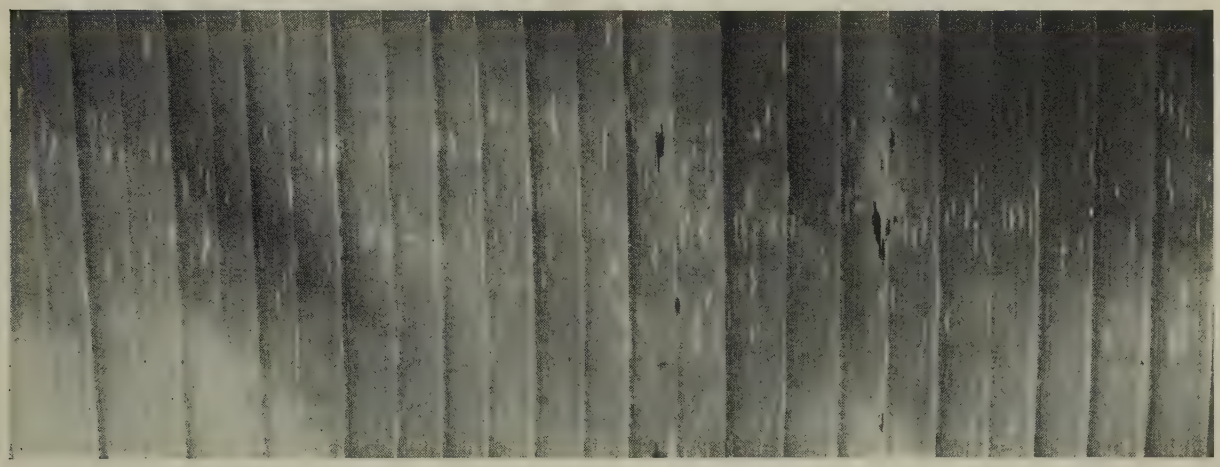


FIG. 15. The streak stage.

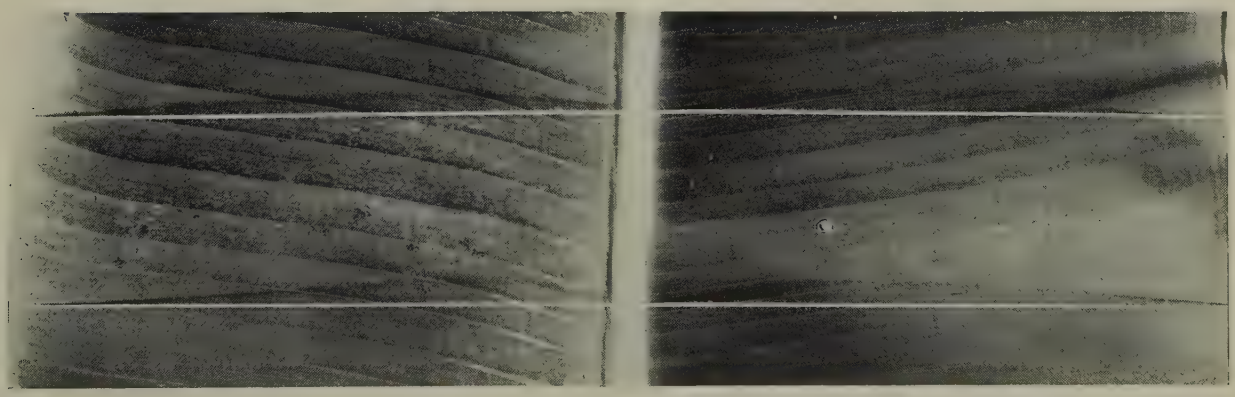


FIG. 16. On left side yellow green *Cercospora* speckles and black *Chloridium* points caused by infection on lower leafside 17 days previously ; unsuccessful infection on the upper right side.

FIG. 18. Leaves infected in the "tongue" stage from the central hole.

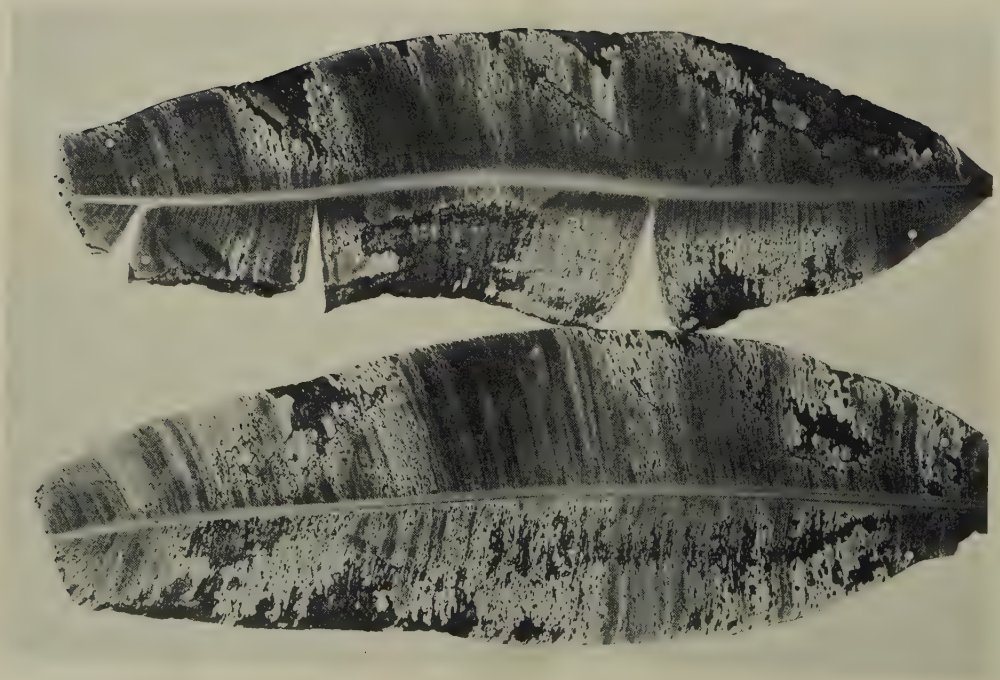


FIG. 17. Leaves heavily infected whilst unfolding.

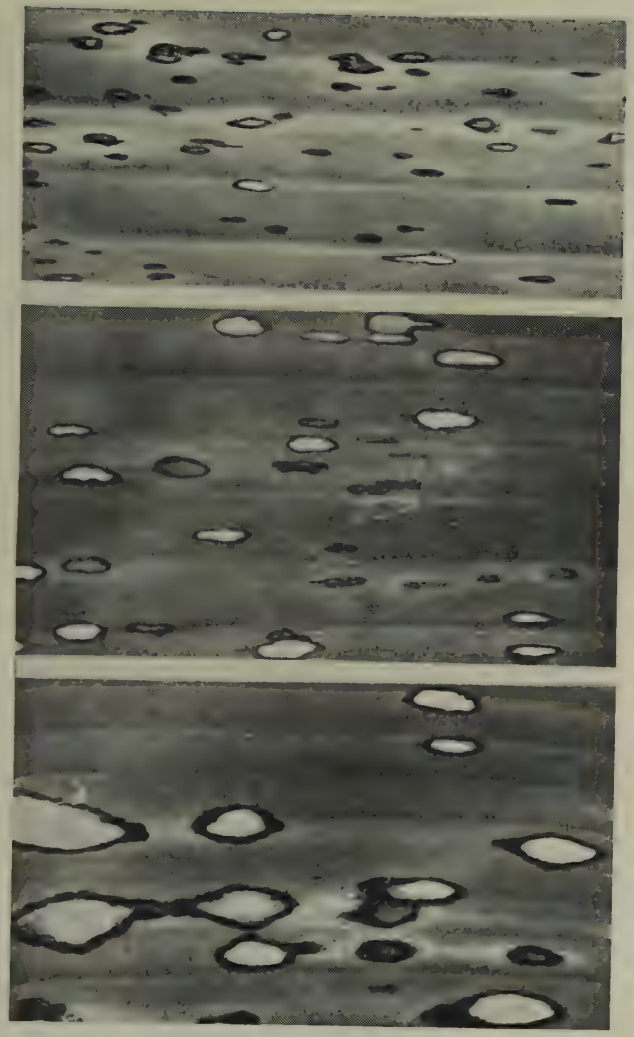


FIG. 20 Typical spots: above, from late infection; middle, normal dry centre spots; below, broad spots on leaf of young plant.

FIG. 19 Infection No 128; second leaf infected 22nd November; right, on the lower side; left, on the upper side; first symptoms 10th December; photographed 28th December.

PLATE VI

Fig. 21. Infection No. 127 : from left to right : first, third and fifth leaf, infected 22nd November, first symptoms 10th—12th December, photographed 2nd January.

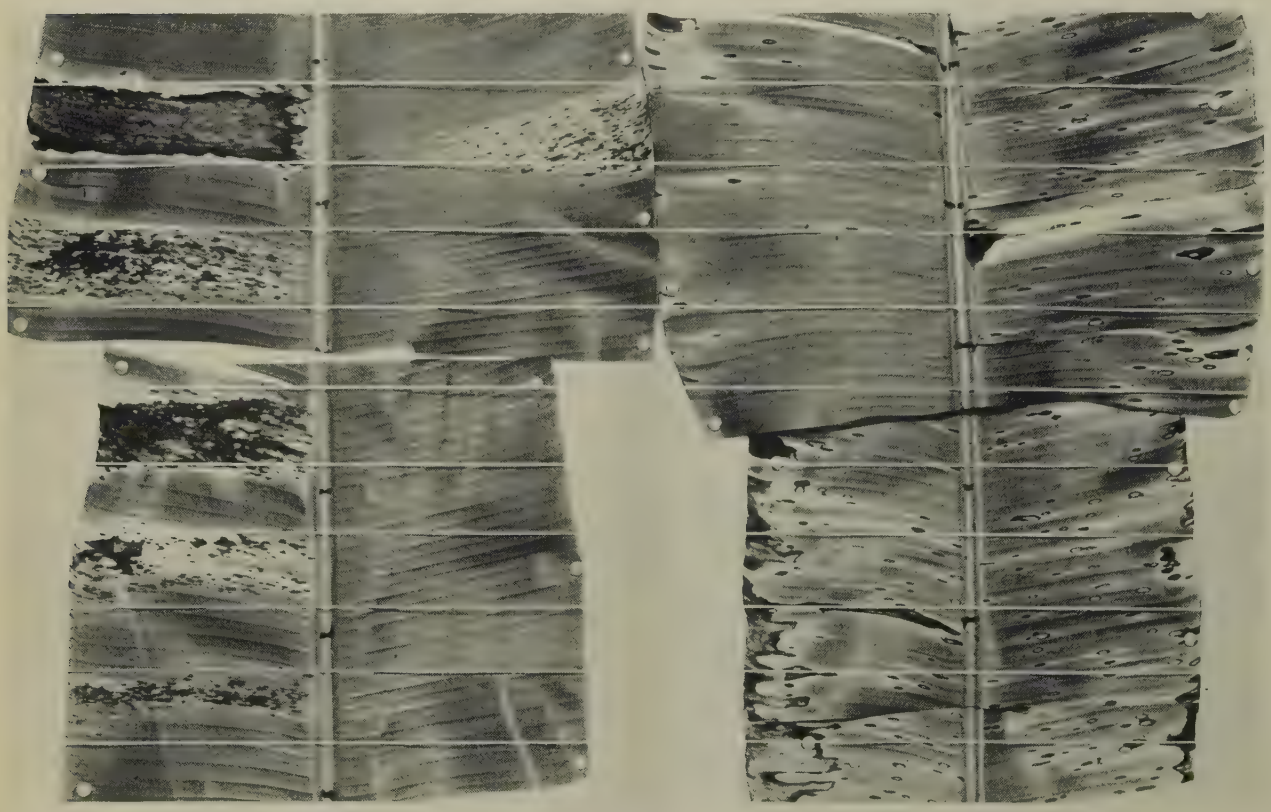


Fig. 22. Left, first leaf ; right, fourth leaf ; infected on the lower side across whole blade ; every successive day one stripe is infected beginning with the upper stripe ; after 7 days the right side is covered with a fungicide ; photographed after 4 weeks ; only after 7 days some of the germ tubes have entered the leaf ; on the fourth leaf at right no infection at all.

PLATE VII

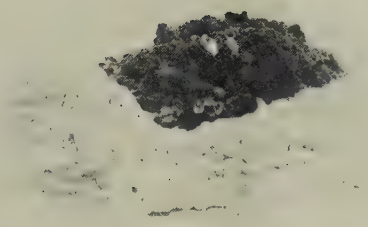


FIG. 23. Black, hard, stromatic mycelium of *Cercospora* on banana fruit, pure culture.

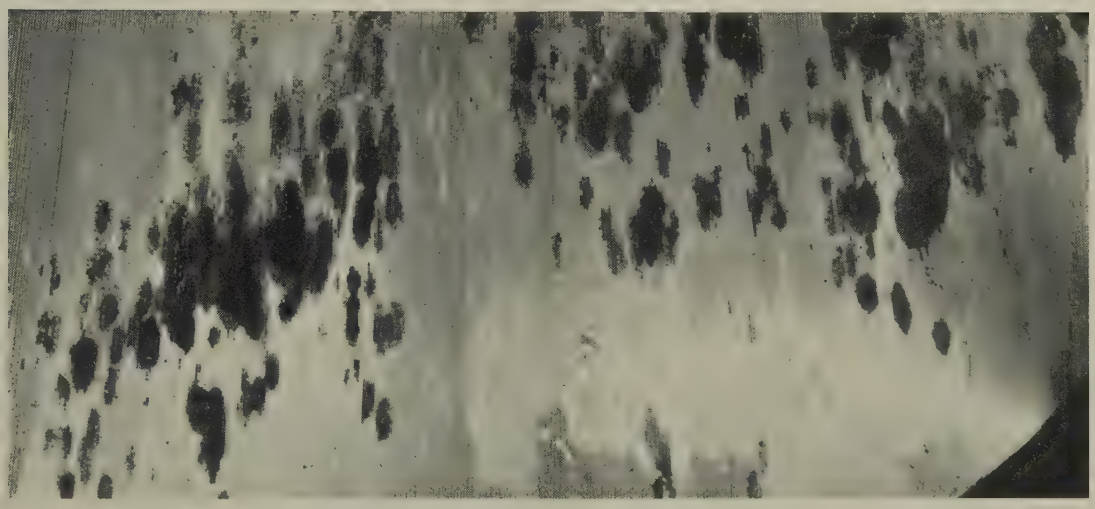


FIG. 24. Leaf with infiltrated spots, reflected light.

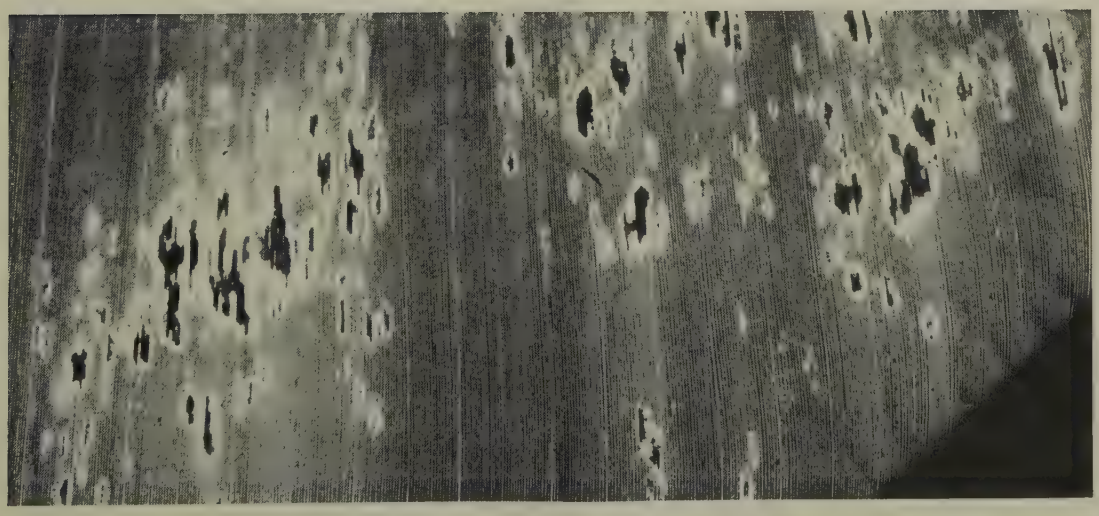


FIG. 25. The same leaf as Fig. 24, transmitted light.

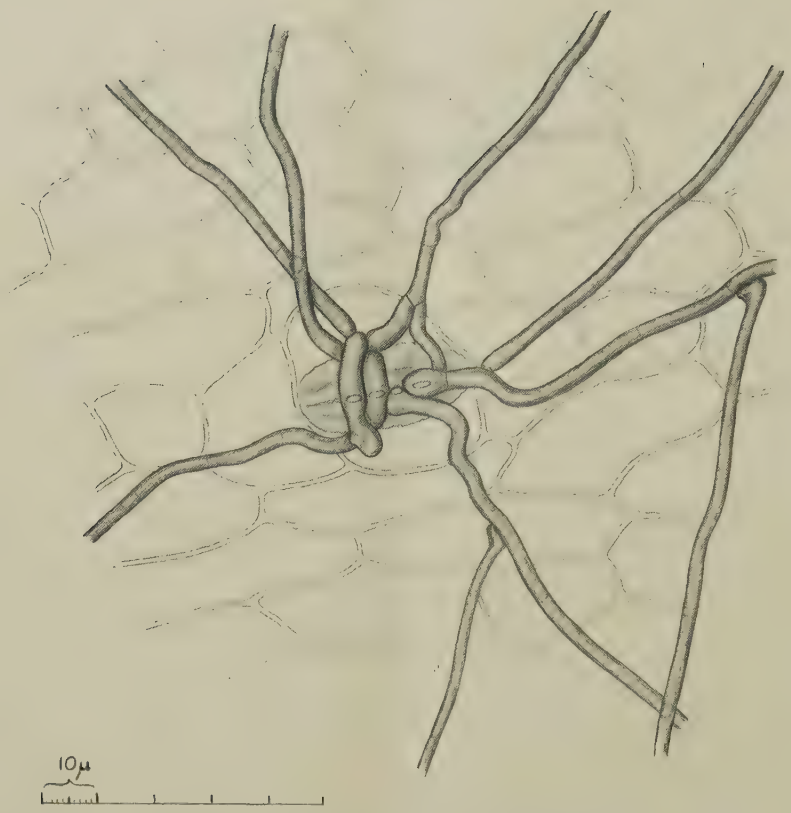


FIG. 26. Dead stoma on the upper surface of a streak with epiphyllic hyphae spreading in all directions. Note the anastomoses at four points where hyphae are crossing, and (bottom right) two hyphae coming from a neighbouring stoma.

FIG. 27. Glass roof with banana plants in trucks.

covered with spots. Dew or generally speaking a film of water is necessary for the growth of the germ tube on the leaf surface.

The infections applied to the third and the older leaves were often entirely masked by natural infection or the leaf was already dead when it was inspected after three weeks. This was avoided in later infection experiments by washing the leaves from the "tongue" downwards every four days. After 40 days the original "tongue" had become the fifth leaf. The leaves were rubbed carefully with a rubber sponge, then rinsed with water and dried with a towel. After this treatment only a few spots were found even on the eighth leaf, and these did not interfere to any extent with the infection experiments.

Method by which Fungus Enters the Leaf and Spreads.

So far nothing is known about the way in which the *Cercospora* germ tube enters the banana leaf. As stated above, the *Cercospora* mycelium does not reach the inside of the leaf before the fifth or seventh day after inoculation.

In order to study the behaviour of the germinated conidia during their very early stages the lower surface of young leaves was sprayed with a concentrated suspension of conidia, and preparations of the epidermis were made daily. After the first night many of the conidia showed a short flat germ tube, which subsequently grew slowly, and firmly glued itself to the leaf surface. On the fourth to sixth day, according to weather conditions, stomatopodia appeared just above the stomatal pores but never elsewhere. The pore is then penetrated by the infecting hypha which forms a big vesicle immediately inside the stoma, to which the protoplasm of the germ tube is transferred. After nine or ten days, therefore, the remains of the exhausted epiphyllic germ tubes are difficult to find. On the upper side of the leaf the germ tube grows over the surface heedless of the stomata. Even when it crosses a stoma no stomatopodium is formed.

From the substomatal vesicle a fine hypha about 1μ in diameter grows out straight through the one or two layers of mesophyll to the inside surface of this tissue. From here it grows to the side wall of the air chamber and along this by the shortest way to the palisade tissue. In only a very few cases have two hyphae been seen arising from one vesicle. The minute hyphae grow between the palisade cells, but are always scarce. Haustoria or intracellular mycelia were never found. From here the hyphae spread to the neighbouring air chambers between the two veins producing the streaks described above. The penetration of the side walls formed by the veins is more difficult. Many of the streaks remain between two nerves or are accompanied by one or two shorter streaks in the neighbouring interveinal spaces.

When the epidermis of mature streaks, showing a rustlike covering is examined, many stomata appear to have died and turned red. In some cases the palisade tissue around the air chamber below a dead stoma is impregnated with a red gum, which causes the rusty appearance of the mature streaks.

The most striking fact at this stage is that everywhere on the streak the *Cercospora* mycelium grows out through the stomatal pores most frequently on the lower surface of the leaf (fig. 26). From here it creeps over the leaf. The hyphae are 3μ thick and brown in colour, whereas the parasitic hyphae in the leaf measure only 1μ and are hyaline. When these hyphae were first seen it was supposed that they belonged to another fungus (*e.g.* to the *Leptosphaeria*), which might penetrate the spots, already at this very first stage, but later many stomata were found with hyphae just growing out and beginning to spread over the epidermis. This mycelium spreads all around the streak as far as 2 to 3 millimetres.

It seemed possible that the guttation, followed by infiltration of the leaf tissue around the streak was caused by a poisonous effect of the epiphyllic mycelium on the leaf tissue thereunder. If that was the case, spraying with a fungicide on young, not yet rusty streaks, should prevent the formation of brown spots. These experiments were unsuccessful. The brown spots appeared at exactly the same time and were of the same size as the controls.

In preparations of the epidermis of such brown spots, that developed after spraying, it was observed that the tissue was dead also outside the streak that was covered by the epiphyllic mycelium and in cross sections no hyphae could be found in the necrotic tissue outside the streak. The guttation therefore must be caused by a toxic effect of the streak itself.

Wolf (9) has described an epiphyllic mycelium of a related fungus, the false mildew of red mulberry *Mycosphaerella* (*Cercosporella*) *arachnoidea*. On the mulberry the fungus also emerges through the stomata on the leaf surface three to four weeks after infection and causes necrotic spots on the leaf, where spermogonia and perithecia are formed just as with *Cercospora musae*.

When the fungus enters the stomata of the infiltrated dead tissue it forms stomatopodia and one or two days later the first acervuli appear in the substomatal air chambers of the brown spot. At this stage some stomatopodia may still be found together with the young acervuli or they are lifted by the growing acervulus and may later be observed between the conidiophores.

The brown spots may subsequently enlarge by renewed infiltration but this growth is arrested after one or two days by the deposition of gum in a 1 mm. broad black band. No callus formation of the surrounding tissues was observed. After one or more weeks the brown spot collapses and turns usually into a greyish white spot with minute black dots caused by the fungus-fructifications described above. The black margin, the border between the spot and the living tissue is free from hyphae and does not collapse.

Briefly, it will be seen that *Cercospora* has first an epiphyllic germ tube stage lasting four to six days followed by a parasitic stage of about 20 days.

The fungus then produces an epiphyllic mycelium that spreads outside on the epidermis. At the same time the tissue around the streak becomes infiltrated and dies in a few hours. The fungus then penetrates the dead leaf spot from the outside and forms *Cercospora* fructifications on both surfaces of the leaf. After the spot has collapsed, the acervuli on the upper surface of the leaf enlarge and spermogonia, and later *Mycosphaerella* perithecia are formed. Perithecia of a *Leptosphaeria* are constanly present on the spot that produces *Hendersonia* pycnidia.

Spraying Hints.

This investigation was undertaken to secure more definite data about the life history of *Cercospora musae*, especially in regard to the manner of infection and in order that the spraying experiments might be conducted as cheaply and as efficiently as possible. The fact that the lower surface of the two youngest leaves has been established as by far the most susceptible to *Cercospora* infection is of paramount importance. The third leaf is less liable to infection, while older leaves are of no practical importance as means of entry for the fungus. The rolled up leaf, the "tongue", is also very susceptible to infection, but here only a small strip along the left margin of the leaf is exposed. The trouble begins when the leaf unfolds and a greater surface becomes accessible to the *Cercospora* conidia. The upper surface of all leaves is unsuitable to infection by the leaf spot fungus since even heavy applications of *Cercospora* conidia resulted, only in a few cases, in a weak infection.

On dead dry leaves hanging down from the banana plant, acervuli still produce some conidia, especially on those that have just died. The average quantity of conidia produced, however, is considerably less than on the living leaves.

Spraying with the purpose of protecting the leaf against infection may be concentrated to the lower surface of the two or three youngest leaves. The spraying experiments carried out on a practical scale by the Surinam Banana Company (Manager J. van Emden) during the past 2½ years, twice or three times a year established the usefulness of this treatment so that spraying is now a permanent cultural operation of this Company. The total cost of one spraying is at present 1.75 dollars per acre. The motor sprayer is mounted on a boat which is easily moved through the trenches to all parts of the fields. At the same time water is available everywhere and spraying is therefore considerably facilitated by the system of trenches in the empoldered Surinam plantations. For spraying purposes the Bayer fungicide with an adhesive is used now as it can be immediately dissolved in water. Originally Bordeaux mixture was sprayed but it took much longer to prepare.

The acervuli on the older leaves continue to produce conidia even after a heavy spraying with the Bayer fungicide. With Bordeaux mixture, the production of conidia is prevented only on the acervuli, which are covered with a strong layer of the spray. Spraying therefore, even with Bordeaux mixture, is of but little use for the reduction of the infective material.

Spraying, however, may advantageously be supplemented in badly infected fields by stripping the older heavily spotted leaves, the source of infection. These should be burnt, buried or removed from the fields. In serious cases a second spraying may be applied, a fortnight after the first, when two new leaves have been formed. In this manner four leaves are protected during the highly infectious period or at least during part of it.

These auxiliary control measures have not yet been tried out here. At the present moment, however, a field is being sprayed and at the same time the stripping of the old leaves is being carried out.

In Surinam there are two outbreaks of the disease in a year, the first takes place in February and the second in July, during the third month of the short and of the long rainy season respectively. Generally, the February outbreak is worse, possibly on account of the lower temperature. In the dry season there is little infection, but during the rainy season the infection accumulates and results in an outbreak towards the end of the season.

An outbreak is the result of a heavy infection which took place about five weeks earlier. Spraying and stripping therefore must be done six to seven weeks ahead, *i.e.* in December and in May. It is possibly more effective and economical to carry out two sprayings and one stripping in December and January before the February outbreak, and only one stripping in May, the heaviest rainy month in Surinam, when spraying is difficult, and the expected outbreaks less severe.

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TROPICAL FRUITS AND VEGETABLES. AN ACCOUNT OF THEIR STORAGE AND TRANSPORT.

By. C. W. Wardlaw.
Low Temperature Research Station.

(Continued from *Tropical Agriculture*, XIV, 8, 1937.)

Nuts.

Nuts are often stored from one production season to the next (1). To prevent the development of rancidity and decay, and to control insect infestation, they are usually held at a low temperature; for the control of pests, a temperature of 50°F. is usually sufficiently low (6).

Pecan and Brazil nuts are more subject to deterioration than walnuts, almonds or filberts. Various reports indicate that walnuts, almonds and pecans can be held at 28°-30°F. (2), 32°F. (3, 4), and 36°-38°F. (2) for upwards of a year without deterioration. In storage trials with pecans, Medlock (5) showed that a temperature of 40°F. was not low enough to maintain this commodity in sound condition for one year. According to Taylor (7), walnuts, almonds and pecans have been held, both shelled and unshelled, for periods of 4 years at 32°F. with only slight deterioration in flavour. At higher temperatures, moisture losses may become important (2). A temperature of 45°-50°F. is also considered satisfactory for walnuts, almonds and filberts (6). Shelled nuts, unless sealed in a vacuum, will not keep as long as unshelled ones. The most desirable moisture content results from storage at a humidity of approximately 65 to 70 per cent. As nuts readily take up undesirable flavours and odours, they should be kept away from apples, potatoes, &c., (5).

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Ochro.

Ochro, or okra (*Hibiscus esculentus*) pods should be harvested when they are four or five days old, *i.e.* when they are young, tender and crisp. Woodroof (2) recommends that harvested pods should be placed under shade immediately and quickly handled to prevent shrivelling and toughening.

Half-bushel baskets are suitable as containers during harvesting, and four-peck hampers for transportation and marketing. Rough treatment is to be avoided. Gloves should be worn by workers to avoid the irritation set up by continuous contact with the stinging hairs.

Shill (1) states that ochroes can be shipped successfully from West Indian Islands to the Canadian market; the storage conditions are not specified.

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ONIONS AND RELATED VEGETABLES.

In this important group are included onions, leeks, chives, garlic and shallots or scallions, most of which can be grown successfully in tropical and sub-tropical regions.

Onions.

Although some varieties of onion (*Allium cepa*) can be kept for long periods in common storage, the use of refrigeration is essential for the satisfactory preservation of others; the modern view is that cold storage offers practical advantages in the handling of all varieties. Losses in onion storage are due to sprouting, root growth, fungal rotting, shrinkage and freezing.

Drying and Curing.

Onions should be well matured and thoroughly cured in the field, in drying sheds or on trays before being placed in storage (6, 17). Experimental records show that the possibility of successful storage depends on the initial quality of the product (14); decay and deterioration tend to occur during the storage of immature, soft, 'thick-necked', or imperfectly cured onions. Slatted crates or shallow bins are the most suitable storage receptacles (2). When cured in the field, bulbs are usually placed in slatted crates, stacked four or five tiers high (6). According to Wright (19) onions, after being pulled, are first of all dried in the windrows for 3 or 4 days; curing, *i.e.* final drying out of the superficial scales, is then effected in slatted crates, stowed in open sheds or under tarpaulins; this operation may continue over several weeks.

The care with which handling, cleaning and drying operations are carried out has important effects on the subsequent storage life. Onions damaged during harvesting, packing or handling, if not thoroughly dried, soon begin to decay in storage (13).

Factors Governing Keeping Quality.

Jones and Bisson (4) have observed that different varieties of onion show very considerable differences in respect of their moisture content. Thus dry weight determinations ranged from about 5 per cent. (of the fresh weight) in the Sweet Spanish variety, to about 16 per cent. in the Red and White Creole varieties. "Evidently those varieties which are considered mild and of rather poor storage quality have the highest moisture content, whereas those that are the most pungent and keep best in storage have the lowest moisture content". The moisture content in individual varieties is also subject to variation according to the growth conditions provided: onions grown on a peat soil were found to have a higher moisture content than those grown on a mineral soil. Similar observations on the relation between keeping quality and dry matter content have been made by Woodman and Barnell (18).

In a detailed study of the relation between keeping quality and rates of water loss during storage, Woodman and Barnell (18) have shown that high relative rates of water loss, and high total water losses, are characteristic of non-keeping varieties of onion. As differences in rates of water loss are particularly apparent during the period immediately after harvesting, they consider that actual storage trials may not be necessary in classifying new lines as keeping or non-keeping types.

Stowage.

Onions for storage should be packed in bags or crates and stacked so as to permit of good air circulation. When stowed in sacks, shelves or racks should be provided to avoid the bruising injury which might result from the weight of super-imposed sacks. Onion rooms should also be completely separated off from other storage rooms to avoid contamination or tainting (13).

When large quantities have to be stored, the bags are piled in pairs laid crosswise in stacks about six bags high. The bottom pair of sacks should be laid on 2 × 4 inch dunnage strips to permit of air circulation; the stacks should also be separated by 2 inch air spaces (11). According to Williams (16), storage in trays or in well ventilated boxes is better than storage in bags, wastage being consistently less.

Storage Temperature and Humidity.

There is a general consensus of opinion that, for successful storage, onions require good ventilation, low temperature and low relative humidity, low temperature being considered more important than low humidity (14). Not only is it necessary to control the growth of moulds, but sprouting and root development must also be prevented.

In storage trials at 32°, 40° and 50°F., with controlled R.H. varying from 65 to 90 per cent., Wright, Lauritzen and Whiteman (20, 21) have shown that the amount of sprouting—an important cause of loss—which occurs during storage is only slightly influenced by humidity but rather definitely by temperature: on the other hand, root formation is only slightly influenced by temperature, but is increased by increasing the humidity. In their experiments the amount of decay did not increase greatly with increased temperature and relative humidity. Onions sets showed an increase in sprouting, rooting and decay as the storage temperature was raised and as the relative humidity was increased at each storage temperature. The best storage environment for both onions and sets was found to be 32°F. with a relative humidity of about 65 per cent. (20).

For onions grown in the United States the following general recommendations, ensuring successful storage up to 6 months with suitable varieties, have been given. At a temperature of 31°-32°F. there is the minimum of decay and no sprouting will occur (6, 11); low humidity is not essential but is desirable; at higher temperatures onions should be kept as dry as possible. "Onions have been kept in good condition at as high a temperature as 40°-50°F. for several weeks when the humidity was kept low. Onions in storage should be kept dry enough to "rustle" like dry leaves when handled. In cold storage at the higher range of temperatures it is usually impractical to keep the humidity sufficiently low, so it is the usual practice to store at 31° to 32°F."(11). According to Platenius *et al.* (6) experimental lots of onions have remained in perfect condition at 30°-32°F., even when the R. H. was as high as 95 per cent.

A temperature of 32°-36°F. in well-ventilated chambers or cellars is advised by Corbett, Stewart and Thompson (2). Friebe-Scupin (3) records successful storage of onions at—3°C.(26.6°F.) and R.H. of 85-90 per cent. for 5-6 months. Rose, Wright and Whiteman (12) recommend a temperature of 32°F. and R.H. of 70-75 per cent. for onions and onion sets, 5-6 months storage being assured. For onions grown in New Zealand, Sutherland (13) cites 31°F. and R.H. of 78-81 per cent. as having given excellent results over a period of six to seven months, and considers that, by concentrating on the production of the more hardy varieties, it should be possible, with the help of refrigeration, to supply local markets throughout the greater part of the year.

Experimental work in Sweden (9,10) has shown that at a temperature of 30.5°F., onion tissue may be altered by putrefaction, mould and germination. On the other hand, a very low temperature, *e.g.*, 19.5° to 23°F., kills the tissue and coagulates the albumen, which, after thawing, remains denatured. At 27°F., the tissue remains unaltered, and, on removal to higher temperatures, is similar to that of fresh onions, a view supported by chemical analyses. (*See* Undercooling.)

Boswell (1) studied the behaviour of onions during, and subsequent to, storage at 32°, 40° and 50°F., and found the lowest temperature most suitable. Onion plants from the lots stored for eight months at 32°F. showed extraordinarily vigorous leaf growth and a scarcity of flower stalk; storage for 6 months at 32°F., followed by 6 weeks at 50°F. resulted in a much more rapid growth than was obtained in bulbs held at 50°F. throughout. Other records (14) also cite 32°F. as being best suited to the storage of onions.

Williams (17) has reported satisfactory storage of Australian onions, held at temperatures ranging from 38°F.. to below freezing point; bulbs held below the freezing point for onions (29°F.) had a particularly good appearance at the end of 3 months' storage. Some varieties, on being thawed out and held at ordinary temperatures gave a better storage life than others. Gradual thawing out (over a period of 2-3 days) was shown to be advantageous, as the onion tissues are very susceptible to rapid changes in temperature. Where this procedure was adopted, the full quality of the onion was retained, so much so that it compared favourably with that of fresh onions. Bulbs stored above freezing point also yielded good results, except that some sprouting took place. As a rule this commodity stored satisfactorily for a period of 6 months.

Handling after Cold Storage.

When onions are removed from cold storage during warm or damp weather, the temperature should be allowed to rise gradually; this will prevent the condensation of moisture; otherwise the bulbs may be liable to severe rotting, particularly if they are loaded tightly into a car or other limited space where drying out is precluded. This danger can be avoided by moving them through a succession of intermediate temperatures till the outside temperature is reached (11).

Loss in Weight.

Losses in weight in stored onions, due to rotting, evaporation, and metabolic processes, may in some instances assume considerable importance. In lots held in ordinary storage for 6 months at Pusa, Walton (15) records losses of 58 per cent. by weight in bulbs stored on racks, and 46 per cent. in bulbs stored in baskets; rotting accounted for 5.5 and 13.1 per cent. respectively of the initial weight.

In onions stored at 29°F., Williams (17) observed a loss in weight of only 4 per cent. in the course of six months, as compared with the 12 per cent. which is customary in common storage. Consignments of Sweet Spanish onions are reported as being subject to severe shrinkage through decay and rooting in storage (14).

In an earlier section attention was drawn to the important relation that exists between keeping quality and rates of moisture loss in different varieties. Woodman and Barnell (18) have demonstrated that water losses take place mainly from the inner and not the outer surface of the scales, and therefore occur mainly through the neck of the bulb. Such losses are greatest immediately after harvesting; later, water loss proceeds at an approximately steady rate. Total losses, under comparable storage conditions, are always greater in non-keeping than in keeping varieties. Thus after 100 days whereas Unwin's Reliance, a keeping variety, had lost only 5-6 per cent. of its initial fresh weight, White Lisbon, a non-keeping variety, had lost approximately 30 per cent.

Undercooling, Freezing and Low Temperature Injury.

From storage data cited above it will be noted that onions may be held below their freezing point without sustaining injury, provided certain conditions are observed. Thus both Williams and Rasmusson indicate successful storage at temperatures below 29°-30°F., the freezing point for onions. The effect of freezing on onions has been the subject of some critical studies by Rasmusson (10) and Wright (19). (A type of physiological breakdown comparable in symptoms to freezing injury has been described by Wright, Lauritzen and Whiteman (20). It was observed both in storage and under field conditions before any actual freezing had occurred; in yellow Globe onions stored at 32°F. a somewhat higher percentage of affected bulbs occurred in lots held in the higher humidity chambers; this type of breakdown is characterised by a very limited amount of watery discoloration in the outer scales only).

In experiments with onions of the Globe type, Wright (20) ascertained that while the average freezing point was in the neighbourhood of 30°F., it varied to some extent according to the temperature at which the onions had previously been stored: for example, bulbs which had been held at 32°F. had a consistently lower freezing point than those stored at 40° or 50°F.

Undercooling.—Although a temperature of 30°F. should be regarded as the minimum storage temperature, it has been observed that onions may be *undercooled* (*i.e.*, cooled below the freezing point without actual freezing of the sap taking place) without sustaining injury.

Undercooling in an onion may be terminated at any time and freezing (*i.e.*, crystallisation of the sap) begun by a sudden jarring or other disturbance. "Therefore when onions are known to be cooled below their freezing point they should be handled with care, since a sudden jar, as when crates are roughly handled or onions are poured from crates or bags to be graded, is likely to start freezing in onions which otherwise would warm up without injury. Numerous tests conducted with undercooled onions have never shown injury caused by cooling below the freezing point, provided they were not permitted to freeze" (19).

The period during which onions may remain undercooled (and uninjured) varies according to internal and other factors. Wright has described experiments in which bulbs held at 22°F. for 2, 4 and 6 days showed 0, 15, and 25 per cent. freezing injury respectively. When onions have been allowed to freeze, the extent of freezing injury is greater if they are transferred to storage at a low temperature, *e.g.*, 32°F., than if they are removed to a higher temperature, say 40°F.; in such an experiment the 40°F. lot only showed 25 per cent. mild freezing injury as against 75 per cent. severely injured in the 32°F. lot; the more severe wastage at 32°F. was presumably in relation to the fact that ice still remained in the tissue, and that the bulbs remained below their freezing point for a considerable time before their temperature rose sufficiently to prevent freezing action.

Freezing Injury.—Freezing injury can readily be diagnosed by cutting open bulbs, when the affected tissues are seen to have a water-soaked, discoloured, transparent appearance, with indefinite scattered opaque areas. Wright (19) states that, "Symptoms of freezing injury are frequently and easily confused with those of physiological breakdown caused by excessive heat and other undetermined factors. When cut, such affected specimens show certain transparent discoloured scales similar to those caused by freezing injury, but usually without the scattered opaque areas. Freezing usually includes an entire scale all or nearly all the way around the onion. Often one scale is found injured while the adjoining ones may be normal. Following light freezing, usually the outer scale only is affected; with more severe freezing the injury is found in the more inner scales, often skipping one or two scales as it penetrates toward the center. The last portion to succumb is the heart or growing point, at the centre of the base or receptacle".

In onions which have been lightly frozen, *i.e.*, where only the outer scales have been affected, serious losses can be avoided if care is taken to dry out the bulbs; the water-soaked scales become dehydrated and the onions, though somewhat softer than before, remain in good condition: in damp storage, on the other hand, decay soon becomes evident.

Blemishing and Discoloration.

Blemishing and discoloration, due to chemical injury, exposure to sunlight, and to fungal organisms have been considered in some detail by Ramsey and Butler (8) and Ramsey (7). Freezing injury has been treated in detail above.

Chemical Injury.—Dark brown or black discolorations of onions, described as "scorched spot" and "bag print", are the result of chemical action by substances in the sack fabric, operating under conditions of damp storage; as a rule the underlying fleshy scales are not injured in any way and eating quality remains unimpaired.

Ammonia Injury.—A uniform and severe type of discoloration caused by the accidental exposure of bulbs to ammonia fumes from the storage plant is occasionally found in onions that have come out of cold storage (7, 8).

> "The fumes cause an alkaline reaction with the color pigments in the outer scales of the onions and often produce pronounced discoloration so that the marketability of the stock is greatly reduced. As a result of exposure to ammonia fumes yellow onions show brown blotches or a uniform brown color over all the exposed surfaces; red onions change to a deep greenish-black or metallic-black color; and white onions are discoloured greenish-yellow. If onions are exposed to strong fumes for several hours the fleshy, edible portion of the bulbs becomes watery, yellowish-green, and worthless.
>
> "Experiments have shown that ammonia injury will take place at a temperature as low as 31.5°F. and that the rate and severity of discoloration are approximately the same as at higher temperatures. The color changes have been found to take place more rapidly in a humid atmosphere or when the onions are slightly moist. Less than 1 per cent. of ammonia in the air will cause marked discoloration if the onions are exposed for 24 hours or longer. With stronger concentrations the color changes are noticeable almost immediately and large brownish-black blotches are produced within a few minutes.
>
> "A similar type of discoloration in colored onions has been observed in stock that had been covered with manure for protection against freezing. The ammonia fumes from the manure cause almost a complete blackening of the outer dry colored scales, but generally do not discolor the fleshy scales."(7.)

Sun Scald.—Onions grown in regions of high temperature and bright sunlight frequently suffer from sun-scald during harvesting, immature and moist bulbs being most severely affected (7). The tissues of scalded areas are killed and become soft and slippery, but soon dry out, leaving bleached, white, sunken and leathery areas, ½-1½ inch in diameter. The blemished areas are also important as a means of ingress for fungi and bacteria (7). Another type of sun injury, described as sunburn or greening, is the result of exposure of bulbs during the growing period or after harvesting (7); green colouring matter develops in the exposed tissue but does not cause death or softening of the affected region. The tissues, however, tend to be bitter and unpalatable.

Fungal Blemishing.—Various fungal pathogens cause more or less severe blemishing, staining or wastage; typical infections have been described as Smudge, Black Mould; Purple Blotch and Soil Stain (7).

Onions Sets.

In general, onion sets require much the same storage conditions as do the mature bulbs. The sets are usually stored in shallow slat-bottom or wire-bottom trays, 4-6 inch. deep, 2 by 3, 4 by 5, or 5 by 5 ft. in size, the trays being stacked so as to leave a space of one inch between the tiers. According to Platenius *et al.* (6), sets of more than one-half of an inch in diameter frequently develop seed stalks before time for bulbing. It has been shown that the temperature at which sets are held during the winter and spring affects the subsequent seed-stalk development, the percentage of seed stalks increasing as the temperature of storage is raised above 30°F.; at temperatures much higher than 32°F., the sets sprout before the time for planting and some decay may result. At 30° and at 32°F. sets keep well and remain dormant until planted; these temperatures are recommended when cold storage is employed (6).

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Leeks, Garlic, Shallots.

Green leeks are best stored at 32°F. with a R.H. of 85-90 per cent.; if properly handled they should keep satisfactorily for 1 to 3 months in storage (2, 3).

Cultivated garlic may be kept at 21°F. without danger; 27°F. also gives satisfactory preservation (1). For dry garlic, Rose *et al.* (3) cite a temperature of 32°F. and a R.H. of 70-75 per cent., giving a storage life of 6-8 months.

For shallots, a temperature of 32°F. is considered suitable (1).

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Papaw.

The papaw or papaya (*Carica papaya*) indigenous to tropical America, has become a food of some importance for local consumption in various parts of the tropics and sub-tropics. It is well known as the source of the digestive substance papain, obtained by coagulating the latex exuded from green fruits on wounding (1). During recent years some attention has been paid to the papaw as a possible export crop notably in South Africa (7, 8, 11, 12) and the West Indies (15, 20), while as early as 1907 Higgins (5) was considering the possibility of exporting the fruit from Hawaii. An attempt has also been made to extend papaw cultivation in California and to breed varieties adapted to prolonged storage or transport (2, 14). From the information available on the production and cold storage behaviour of papaws, it may be predicted that the organisation and standardisation of an export industry will be attended with serious difficulties.

Selection of Desirable Types.

The papaw shows great variety in its fruiting characters, some types producing small fruits, spherical and no larger than an orange, and others elongated fruits as large as a watermelon and weighing up to 25 lb. The immature fruit is firm and green with a thin waxy cuticle, the flesh being of a whitish or greenish-white colour. On ripening, the flesh becomes soft, and of a pale-yellowish to dark reddish-orange colour according to the variety; externally the fruit has a yellowish or orange colour. Flavour varies from varieties which are insipid and tasteless to those which are sweet and spicy. According to Barrett (2) the fruit, even when immature, contains no starch.

Fruits for export should be of smallish or intermediate size and of a shape suitable for packing side by side in a standard crate. They should possess a reasonably tough skin to minimise the effect of bruising and should show some degree of resistance to the normal storage pathogens. Lastly, in addition to obvious, essential requirements in the matter of attractive appearance and colour, flavour and thickness of flesh, the constitution of varieties selected should be such as to make for good keeping quality in storage. In all of these respects great variability is the rule.

In working towards an export trade, standardised production under plantation or orchard conditions is a first essential. The difficulties attendant on the field aspect cannot be over-emphasised. The outstanding problem is to select and perpetuate good types from material which is notoriously variable. Again, most varieties are dioecious so that, in establishing an orchard the liability to a low standard of production is accentuated by the number of male plants present in a sowing. Hoffmeyr (7, 8) has indicated the possibility of improving stocks by selection, the main points in a selection programme being (*a*) keeping and shipping quality, (*b*) suitable shape and size for packing, (*c*) colour when ripe, (*d*) eating quality, (*e*) thickness of flesh, (*f*) length of fruit stalk, (*g*) disease resistance, (*h*) yield and vigour. Some hermaphrodite varieties are known (18) and it has also been shown that cutting back male plants frequently, though not invariably, causes a change of sex (2, 9, 16, 17). According to Hoffmeyr (8), there are no true-breeding papaw varieties, and observations in any grove will reveal great variability in shape, size and quality of fruit and vigour of plants.

Attempts have been made in Hawaii (18) to breed a hermaphrodite strain and it has been demonstrated that it is possible to increase the percentage of fruit-bearing plants. Unfortunately no means of early sex-diagnosis has yet been discovered. As a rule no difficulty has been experienced in crossing the various types: the trouble lies in the fact that it has not yet been possible to fix the desirable types obtained by crossing. Some papaw varieties are seedless. According to Cheema and Dani (3) this is due entirely to the absence of pollination, the size and weight of a fruit being related to the number of seeds it contains.

Up-to-date accounts of general cultivation and marketing requirements are given by Pope (13), Nyenhuis (11, 12), Hoffmeyr (7, 8), Cheema and Dani (4). In the West Indies, orchard difficulties are accentuated by the presence of a widespread virus disease which completely destroys the crown of foliage with concomitant loss of crop.

Maturity, Storage Temperature and Chilling.

One of the earliest accounts of papaw storage is that given by Higgins (5), working in Hawaii. Fruits for local consumption, according to Higgins, should be picked when they show the first trace of colour. When fruits of this maturity were wrapped in paper surrounded by a sleeve or cylinder of crimped strawboard, placed side by side in a single layer in a flat crate, and shipped to San Francisco—a voyage of 7 days in cold storage (temperature not specified)—fairly satisfactory results are said to have been obtained. The wastage recorded ranged from 7 to 44 per cent. It is stated that the fruit did not deteriorate in flavour. Wilcox and Hunn (22) have also given some account of six Hawaiian varieties stored in cold chambers maintained at 32° and 36°F. The results were generally unsuccessful: these temperatures are now known to induce chilling, with concomitant excessive wastage later. Nearly ripe fruits, *i.e.*, yellow coloured but firm, washed with 3 per cent. formalin to prevent or curtail the growth of moulds, are stated to have kept in good condition at either temperature for one month to six weeks.

McGuire (10) records that an experimental shipment of a few cases of papaws was made from South Africa to London—a transit period of approximately 24 days at 38°-40°F.—but no marketing data are available.

Nyenhuis (11), referring to papaws grown in Northern Transvaal, states that fruits, after careful washing, were wrapped in tissue paper and placed in cases, 4 fruits to the case, with a plentiful packing of wood-wool. The cases were sent in refrigerated trucks to the Capetown Low Temperature Research Station for further observation, where they were stored for 3 weeks at 36°, 40° and 45°F. and a R.H. of approximately 90 per cent. Two stages of maturity were selected for investigation: (*a*) fruits full-grown, dark green but showing the first trace of yellow; such fruits were considered sufficiently mature to ripen after long storage; and (*b*), riper fruits of pale green colour, the yellow colour being distributed fairly evenly over the surface.

On removing fruits from cold-storage after 3 weeks, very little advance in ripening could be detected; those at 40° and 45°F. were becoming mouldy, particularly on the lower side. After 5 days' exposure at room temperatures no appreciable ripening had taken place but wastage

due to fungal activity was conspicuous. Further exposure at the higher temperature failed to induce normal ripening. After 14 days, the greener fruit grade (*a*) had failed to ripen and the more mature grade (*b*), though ripe, was wasty and of poor flavour.

Storage trials carried out in Trinidad in 1933 (20) and subsequently have shown that relatively immature papaws will not ripen after cold storage, and further, that most of the varieties tested show evidence of chilling if held at temperatures lower than 55°-60°F. Fruits at three stages of maturity (*a*) full-grown green, (*b*) with first traces of yellowing and (*c*) more or less completely yellow but still firm, were held for periods of 15 and 20 days at 45° and 50°F. Small lots were ripened at tropical temperatures, 80°F. approximately, for comparison. The following observations were made. Wastage was serious at both cold storage temperatures, but was noticeably worse in fruit held at 50°F. It was evident that some types of papaw possess greater resistance to pathogenic fungi than others. In the course of 20 days at 45°F. and 50°F. respectively, apart from the onset of wastage, there was no evidence, as judged by external criteria, that maturation had advanced significantly in any of the three classes of fruit. Even the yellow fruits were still quite firm, and apparently unaltered from the time of reaping. Green fruits, on transference to the ripening room at 70°F., failed to ripen and were soon overrun by various fungi or partly shrivelled before any trace of colour appeared. It is evident that fruit reaped at this stage of maturity is quite unsuitable for export. Slightly coloured fruits were little better as regards external appearance, but became soft and were quite palatable. The almost fully coloured fruits, on the other hand, were normal in behaviour. In some types, in which storage pathogens had become established, degeneration at the higher temperature was rapid and within two days the fruits were unsightly and unfit for use. A few of the yellow fruits, however, undoubtedly possessed a better keeping quality and were still in good condition after three to four or five days at 70°F. The inference is that fruit for export should be reaped when yellow but quite firm, and held at 45°F. There was also definite evidence that some varieties on transference to the ripening room or if held at tropical temperatures ripen more rapidly than others. In attempts to secure a partial ripening of green or slightly yellow fruits by holding them for a few days at tropical temperatures prior to cold storage, the subsequent wastage was excessive (20).

These results, indicate that the overseas transport and distribution of papaws is by no means impossible provided suitable types can be selected. It is also evident that fruits should be well coloured but still firm at the time of reaping. As these remain practically unchanged during 20 days storage at 45°F., they should, if carefully packed, be available for retailing on distant markets. In handling a delicate fruit like the papaw, it would be an advantage if some refrigeration could be given during the distribution period. The handling of green or slightly coloured fruits at a higher storage temperature, say 55°F. to 60°F., to permit of partial ripening during the voyage period, is precluded by the onset of fungal wastage at temperatures above 50°F. (20).

Ethylene Ripening.

According to Harvey (4A) papaws picked sufficiently green to withstand shipment can be ripened to a product of agreeable flavour, comparable to that of fruits ripened in the tropics, by the use of ethylene gas.

It has been found that papaws are very susceptible to low temperature injury: chilled fruits fail to ripen and acquire a smoky or sooty greenish-yellow colour and are particularly subject to fungal attack.

Fungi Causing Wastage.

The wastage which develops when papaws are held in storage is principally due to *Colletotrichum gloeosporioides* (anthracnose spots), established as latent infections during the development of the fruit in the field. Normally these only become apparent when the fruit is approaching final maturity in storage (19, 21) but they may also occur in less mature fruits which have been held at chilling temperatures. So far, spraying with fungicides in the field and steeping fruits in disinfectant solutions have not yielded the desired reduction in rotting (20).

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Parsnips.

Boswell (1), studying the parsnip from the point of view of changes in quality and chemical composition during storage, found that roots may be rapidly brought to a state of high table quality by storage at 32° to 34°F.: the hydrolysis of starch and other polysaccharides proceeds much more rapidly than at ordinary temperatures, with concomitant accumulation of sucrose. The commercial value of this vegetable is enhanced by holding it at a temperature of 32° to 34°F. for three weeks. A temperature of 32°F., and R.H. of 90-95 per cent. should ensure a storage life of 2-4 months (3, 4). Platenius *et al.* (2) state that when stored at 45°F., parsnips lose moisture and deteriorate rapidly.

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PASSION FRUITS.

The Passifloras to which attention has been directed in storage literature include the purple granadilla or passion fruit (*Passiflora edulis*), the sweet granadilla or water-lemon (*P. ligularis*) and the giant granadilla (*P. macrocarpa*).

Passion Fruit.

The purple granadilla or passion fruit, native to Brazil, is now grown throughout the tropical and sub-tropical belt, reaching its greatest economic importance in Australia (9). The commonly grown species, *P. edulis*, is very prolific and when fully matured has a dark purple skin, sub-acid flavour and a distinct agreeable odour (4, 9).

Harvesting, Grading and Packing.

Pope (8) states that gathering and handling should be done while the fruit is cool, and that Hawaiian fruit intended for shipment should be cut from the plants when it is just approaching the full colour of ripeness. The best flavour is obtained in fruit fully ripened on the vines. According to Krone (6), Australian fruit should not be harvested at the beginning of the season until it has completely changed to its darker colour but before any sign of shrivelling has appeared. As the season advances picking at a less mature stage is desirable; the correct picking maturity is indicated when fruits have become more than three parts coloured; this allows for the completion of ripening during transport, storage and marketing. In hot weather fruits should be harvested just colouring (4). Fruits harvested immature fail to ripen properly; instead of the normal dark purple colour developing, such fruits assume a reddish colour and may shrivel before becoming fully coloured (4).

Fruits should be collected daily, windfalls being picked up first as they are quickly ruined by exposure to hot sunlight.

The view has been expressed (2) that fruit from correctly pruned vines is superior in quality to that from badly pruned or unpruned vines; the pulp is more luscious and of finer quality and the skin of harder texture. The fruit should be collected in padded field boxes. Careful handling is particularly important in consignments intended for export (4, 8).

Krone (6) and Gregory (3) direct attention to the importance of careful grading and packing. "Dummy" *i.e.*, light weight fruits, should never be packed along with fresh fruits. Three grades, "special", "standard" and "plain" have been suggested for Australian produce, according to size, succulence, woodiness and shrivelling exhibited by fruits. Desirable types of cases and systems of packing have been described in detail by Krone (6) and others (4, 7).

Storage Temperature.

The passion fruit has long been considered unsuitable for prolonged storage; fermentation of the pulp, shrivelling and fungal decay all militate against the preservation of this delicate fruit. In an early reference, Benson (1), 1893, states that passion fruit cannot be held in cold storage in good condition for more than 2 weeks.

In storage trials at 36°F. with Australian passion fruit, commenced in 1929, Savage and Ramsay (10) record only moderately good results. By the end of the second week in storage, the fruits, whether packed with or without peat moss, had acquired "papery" skins. By the end of 6 weeks, apart from the development of moulds, the skins had become very thin and there was a general depreciation in flavour. At this stage, moss-packed fruits had a slightly better appearance than the others.

It is considered that harvesting at the correct stage of maturity, trimming the stem-ends close to the fruit, and quick cooling will contribute materially to the successful transport of this commodity (2).

Recent investigations, conducted under the auspices of the Australian Council for Scientific and Industrial Research indicate that passion fruit will not stand low temperatures. In storage experiments at 36°, 43°, and 50°F., it was found that a storage life of only 4-5 weeks could be anticipated and that low temperature breakdown, in the form of a blood-red discoloration of the skin quickly followed by mould attack, occurred at temperatures below 50°F. (12). Some gas-storage experiments, using 5 to 15 per cent. carbon dioxide at a storage temperature of 45°F. have been carried out, but further investigations are required (5).

Waterlemon or Sweet Granadilla.

According to Wilcox and Hunn (14) consignments of this fruit, grown in Hawaii, kept in good condition for periods of 2-3 months at storage temperatures of 32°F. and 36°F. "At the end of that time, the appearance of the rind, the fibrous bag inside the rind, and the pulp of the fruit were the same in all respects as when the fruit was put in cold storage." Wilcox and Hunn comment on the difference between results with Hawaiian fruit and those obtained with passion fruits by Benson in Australia.

The Giant Granadilla.

This species has the largest fruit among the Passifloras; its quality, however, is inferior to that of other edible species. While it is widely distributed in the tropics, it is nowhere cultivated on a commercial scale.

Some experiments on the storage behaviour of granadillas have been carried out in Trinidad (13). Fruits picked green, turning, and yellow were stored in small quantities at 50°F. for 17 days, then transferred to the ripening room at 70°F. After seven days at 50°F. the yellow fruits, which were already almost ripe on reaping, had become over-ripe, soft and leaky. Green fruits showed little change during the entire period in cold storage, but turning fruits showed a slight increase in colour. In the course of seven days at 70°F., turning fruits became quite ripe and soft and green fruits became slightly coloured, soft and ready for use. In a second experiment, green and turning fruits were held at 45°F. for 15 days and subsequently ripened at 70°F. in the course of seven to ten days.

If required for export, this fruit should not prove difficult to handle. Although prized locally for the preparation of ices and drinks—the pulp has a pleasant sub-acid flavour—the cost of crating and freight for such large fruits (some are nine inches long) would seriously militate against its economic disposal on distant markets (13).

Smith (11) has recorded that very large granadillas, when reaped mature, can be stored at 47°F. for a considerable time without deterioration; fruit reaped less mature was unpalatable after cold storage.

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Peppers.

Peppers and chillies (*Capsicum* spp.) are represented by many varieties in the tropics. Sweet peppers for export are usually reaped when full grown but green (3); Smith (7) records that mixed lots of red and green fruit make an attractive pack and have been favourably received by the trade.

Packing.

Peppers, from which over-ripe and sun-scalded fruits have been eliminated, are graded for size, packed in what is known as the American pepper crate, or in smaller slatted cases lined with glazed tissue paper. Jamaica exporters have found a hinged crate measuring $16 \times 11\frac{1}{2} \times 9$ inch to be satisfactory and acceptable. Wrapping of fruits has not been found necessary (7).

Storage Temperature.

The most comprehensive consideration of the effect of storage temperature and humidity on the keeping quality of peppers is that of Lauritzen and Wright (2). Fruits were held at four temperatures, 0°C. (32°F.), 4.5°C. (40.1°F.), 10°C. (50°F.) and 13°C. (55.4°F.) several different humidities being provided at each temperature. The chief causes of wastage were infection and rotting by *Botrytis cinerea* and anthracnose.

Ripening continued at all four temperatures, but was very slow at 32°F. In green fruits ripening was sufficiently slow at both 32° and 40°F. to permit of storage for upwards of three or four weeks. Indeed little advance in maturation took place at 32° and 40°F. in the course of 39 days. The higher the temperature and the lower the relative humidity the greater was the extent of shrivelling: a temperature of 40°F. and R.H. of 95 per cent., or a temperature of 32°F. and R.H. of 90 per cent. provided conditions favourable to the storage of peppers. Of the two storage conditions the latter was to be preferred: the limiting factor at the high relative humidity employed was infection and rotting by *Botrytis cinerea*, but as the earliest infections were only observed after 32 days, and the amount of wastage remained small until after 46 days, a reasonable storage life is assured. The time required for the initial growth of Botrytis at 40°F. and 50°F. was about 18 days. From data submitted by investigators it is evident that the anthracnose fungus is already present in fruits prior to storage in the form of latent infections: hence, although their development is influenced by the temperature factor, it is little affected by humidity.

For American produce it has been stated that green peppers can be kept from one to three weeks at 32°F. with a humidity of 90 to 95 per cent.; at this temperature will be found the minimum of decay, shrivelling and ripening (5). A more prolonged storage life has been cited by other workers. Thus from experimental trials, Platenius *et al.* (4) state that peppers remained in good condition for 10 days at 70°F. (breakdown being caused by softening, wilting and shrivelling), 16 days at 50°F., 28 days at 40°F., and 40 days at 32°F. At the lower temperatures the peppers remained firm and smooth until they became spoilt by the inroads of fungi. Platenius *et al.* consider that if mould growth could be curtailed, a storage life of two months should be possible. Peppers held at 30°F. did not show signs of freezing injury, and kept as well as those at 32°F. As compared with other vegetables, the rate of water loss is low, only 4 per cent. being recorded in 40 days.

Smith (7) states that small quantities of sweet peppers have been successfully shipped from Jamaica to Canada, and that trial shipments are now being made to England. For dry Chile peppers Rose *et al.* (6) cite a storage temperature of 50°-80°F.

Freezing Injury.

Freezing injury (2) is characterised by the development of a soft, watery, flabby texture in affected tissues, accompanied by the production of a deadened darker colour; small areas only, or the entire fruit, may be involved according to the severity of the exposure. These changes are in marked contrast to the normal firm, brittle tissues of uninjured fruits.

When a frozen fruit is cut open the soft tissues ooze water freely. The seeds, normally white, also acquire a darker colour. Such freezing injury was induced experimentally by exposing fruits to an average temperature of −1.06°C. (approximately 30°F.). Chilling injury, produced at higher temperatures than those required to freeze tissues, may be expected to be considerably less serious.

Carbon Dioxide Treatment.

Brooks *et al* (1) have observed that peppers are injured by medium and high concentrations of carbon dioxide, the superficial tissues of the fruits becoming pitted, scalded and discoloured.

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SUGAR NOTES.

Compiled by the College Department of Sugar Technology.

Errors in the Determination of Pol. in Bagasse.

In Queensland mills two methods of analysing bagasse for pol. are in use, viz.: (*a*) that described in the "Laboratory Manual for Queensland Sugar Mills", and hereinafter referred to as the Queensland Method; and (*b*) that according to the "Chemical Control for Cane Sugar Factories" of the Association of Hawaiian Sugar Technologists, referred to as the Hawaiian Method.

The prevalence of the use of the latter method results from the fact that for many years the Hawaiian handbook provided the only reference book for mill analytical procedures in Queensland. The only essential difference between these two methods is that in the former the bagasse is diluted for extraction in the ratio of one part of bagasse to 10 parts of water, whilst in the latter method the ratio is one to five.

In a recent investigation by the writer these two methods were examined and their accuracies determined, the method of analysis developed by Khainovsky* used as standard. The results obtained from this investigation (to be summarized more fully later) may briefly be stated as follows:—

The average error of the Hawaiian method is about - 11 per cent. of the pol. in bagasse, or – 0.22 per cent. when referred to the total bagasse. That of the Queensland method is about – 2.5 per cent. of the pol in bagasse, or – 0.05 per cent. when referred to the total bagasse.

The error in the Queensland method is negligible for ordinary routine control purposes, but that in the Hawaiian method is far too great to be ignored. This large error has been attributed to the fact that with the low ratio of extraction water to bagasse in the Hawaiian method, there is insufficient liquid to provide the good circulation shown by Khainovsky, to be essential for complete extraction.

It is considered necessary that action be taken by the Manufacturing Section of the Society to adopt the Queensland method as the standard routine method for mills in Australia.—(*Inter. Sugar Journal*, Vol. XXXIX, No. 463, 1937, pp. 273-74.)

* *Archief*, Meded. 1927.

* * *

Milling Equipment: Factors in Design and Operation.

This paper is a general discussion of some practical problems of mill speeds, volumes and settings; some original ideas on mill setting are included, based on experience with tandems doing good work on canes with 11 to 13 per cent. fibre. For these circumstances the desired opening between the rolls in inches is given by the formula $d = \frac{V}{12s}$ where d is the required opening in inches, V the passing volume of fibre in cub. in. per min., and s the roll speed (average at centre of grooving) in in. per min.; the values for V are taken from a previously prepared table or graph for each unit of the tandem. In proportioning turnplates an entrance area 50 per cent. greater and a discharge area 90 per cent. greater than the mill's primary opening area is very satisfactory. The author is not much in favour of drainage grooves in the back or bagasse rolls.—(*Inter. Sugar Journal*, Vol. XXXIX, No. 463, 1937, p. 278.)

* * *

Sulphur-burning Equipment at Kohala and Hawi, T. H.

In order to contend with the refractory juices of the new canes, sulphitation has been introduced into several of the factories in the T.H. At Kohala and Hawi a rotary-type burner was installed. It consisted of a horizontal drum, 32 inches long and 16 inches in diam., with 14 inches cones at each end. A ¼ h.p. motor operating through suitable reduction gears rotated it once every 2 min.

On the inside of this burner is a piece of 8-inch pipe, 30 inches long, perforated with ⅝ inch holes, spaced 3 inches apart, which is free to roll with the burner as it rotates, picks up the molten sulphur from the bottom and exposes it to the air. This increases the capacity of the burner and gives a better flame.

The sublimation chamber is 3 feet square made from c.i. plates bolted together and baffled to give a longer time for the completion of combustion before the gases reach the water-jacketed pipe leading to the sulphur tower. The draught is maintained by a blower and venturi tube at the top of the sulphur tower. The sulphur fed into the burner is controlled by a mechanical feeder consisting of a slow-moving scroll in the bottom of a hopper, turned by a ¼ h.p. motor working through a set of reduction gears. By varying the speed of the scroll, one can vary the amount of sulphur burned from 15 to 50 lb. per hour. The use of this mechanical feeder has given a much steadier feed and consequently more uniform results at the settling tanks.

The factory staffs have proven to their satisfaction that with all the juices they handle, and the equipment which they have, the benefits from the use of sulphur more than offset the disadvantages, which are: (1) additional scale in heaters and evaporators; (2) a lowering of the purity between mixed juice and syrup, and (3) the actual cost of the sulphur and additional lime required. As for this latter item it has been found to be between 30 and 32 cents per ton of sugar made, some of the figures being:

Cane ground, tons (cane ratio, 9.35)	102,235
Sugar bagged, tons	10,924
Sulphur burnt, lbs. (at 1.8375 c. lb.)	103,250
Additional lime used, lbs. (at 1.079 c. lb)	146,196
Total cost of lime and sulphur, c. per ton sugar	31.8

—(*Inter. Sugar Journal*, Vol. XXXIX, No. 463, 1937, p. 282.)

TREND OF THE MARKETS.

[The notes below are based principally upon running charts of the prices of the basic grades and upon general statistical information gleaned from contemporary publications and cablegrams and are intended to be a record of movements. An attempt is made, where possible, to indicate the market outlook at the time of going to press, but no responsibility for the accuracy and subsequent truth of such observations is assumed. Unless otherwise stated the prices quoted are spot, London.]

SUGAR.—Prices on the Home Markets have ranged as follows (c.i.f. per cwt.):—

	Foreign.		*Preferential.*	
	s.	*d.*	*s.*	*d.*
24th June	6	8¼	10	4½
1st July	6	8¼	10	5½
8th July	6	7½	10	4½
15th July	6	7½	10	4½
22nd July	6	7½	10	4½
29th July	6	8¼	10	4¼
5th August	6	7½	10	4½
12th August	6	8¼	10	5¼
(*13th August*, 1936)	4	5½	8	2¼

The market has continued very steady and quotations, after very moderate fluctuations, have remained about the same. The American market has been rather unsettled owing to uncertainty in regard to sugar legislation.

* * *

RUBBER.—Quotations for plantation sheet have ranged as follows:—

	Pence per lb.
30th June	9 7-16
7th July	9 1-2
14th July	9 3-16
21st July	9
28th July	8 13-16
4th August	8 7-8
11th August	8 13-16
(*12th August*, 1936)	7 9-16

Periods of weakness and firmness have been experienced by the market. Quotations on balance are slightly lower. The uncertain outlook in Europe and the strike situation in America continue to act as a drag on the market but the factor mainly responsible for an easier tone has been a substantial increase in exports from the principal producing areas. Stocks in the United Kingdom, however, have continued to decline while American consumption for June at 51,798 tons has been maintained. No changes were made in the quotas by the International Rubber Regulation Committee which met on 20th July.

* * *

BANANAS.—Jamaicas are quoted at £19 5*s.* delivered London and £19 nearest Station Provinces.—(*West India Committee Circular*, 29th July.)

* * *

COPRA has again been dull and the value of West Indian f.m.s. is £16 7*s.* 6*d.* spot and £16 10*s.* forward c.i.f. London.—(*West India Committee Circular*, 15th July.)

COCOA.—During the past month the cocoa market has advanced somewhat, the firmness being attributed to renewed speculative interest, and restricted offerings emanating from primary markets. With the months of heavier arrivals and the active grinding season fast approaching the future regarding trend of prices is problematical. Locally $12.00 per fanega is paid for Plantation cocoa and Accra is quoted at 35*s.* 6*d.*—(*By Courtesy of the Cocoa Planters' Association of Trinidad, Ltd.*)

* * *

COTTON.—The following are the official spot prices in pence per lb. of the Liverpool Cotton Association.

	American Mid.	*Egyptian F.G.F. Sakel.*
25th June	6.95	11.05
2nd July	6.87	9.70
9th July	6.98	10.07
16th July	6.85	10.05
23rd July	6.60	9.75
30th July	6.63	—
6th August	6.30	—
13th August	5.93	—
(*14th August*, 1936)	6.92	11.01

Prices have been easier due to unfavourable political news from abroad which has caused a good deal of anxiety. The American Government's estimate of the area under cotton cultivation at 34,192,000 acres represents an increase of 10.4 per cent. over 1936. Weather advices have been favourable and a heavy yield has been forecasted. Only a small business is reported in Sea Island at prices ranging from 22*d.* to 24*d.* per lb.

* * *

COFFEE.—Conditions have been very quiet. Costa Rica country cleaned realised 70*s.* 6*d.* per cwt. and London cleaned up to 70*s.* per cwt. Kenya prices have been ranging from 60*s.* 6*d.* to 71*s.* per cwt. Jamaica bold sizes sold up to 221*s.* per cwt. and Santos Superior realised 53*s.* 6*d.* f.o.b.

* * *

LIME PRODUCTS: *Lime Oil.*—The value of handpressed is nominally 40*s.* but sales are slow. Distilled is firm at 25*s.* *Lime Juice.*—There have been buyers at £5 17*s.* 6*d.* in limited quantities for shipment. The value of raw is unchanged at 2*s.* to 2*s.* 3*d.*—(*West India Committee Circular*, 15th July.)